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TRANSACTIONS

OF THE

MANCHESTER

GEOLOGICAL AND MINING SOCIETY.

EDITED BY

THE HONORARY SECRETARY.

VOLUME TWENTY-NINTH.

PARTS I.—X.

FOR SESSIONS 1904-1905, AND 1905-1906.

MANCHESTER:
PUBLISHED AT THE ROOMS OF THE SOCIETY,
5, JOHN DALTON STREET, MANCHESTER.

MDCCCCVI.

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*** The writers of papers alone are responsible for the facts and opinions contained in their respective communications.

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PART I. VOL. XXIX.

TRANSACTIONS

OF THE

MANCHESTER GEOLOGICAL & MINING SOCIETY.

EDITED BY

THE HONORARY SECRETARY.

SESSION 1904-1905.

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TRANSACTIONS

OF THE

MANCHESTER

GEOLOGICAL AND MINING SOCIETY.

ANNUAL MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
OCTOBER 11TH, 1904.

COL. GEORGE H. HOLLINGWORTH, RETIRING PRESIDENT, IN THE CHAIR.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. VINCENT BRAMALL, Mining Engineer, Pendlebury Collieries, Pendlebury, near Manchester.

Mr. ROBERT LORAINE GAMLEN, Mechanical and Electrical Engineer, 78, King Street, Manchester.

Mr. FREDERICK H. HOLLINGWORTH, Mining Engineer, The Oak, Hollinwood, near Oldham.

Mr. GERALD H. J. HOOGHWINKEL, Mining and Electrical Engineer, Dacre House, Victoria Street, London, S.W.

Mr. WILL SETTLE, Mining Engineer, Prestwich.

Mr. RICHARD SYDNEY SPENCER, Mining Engineer, New Moss Colliery, Audenshaw, near Manchester.

STUDENTS—

Mr. HUGH CRANKSHAW, Mining Student, Montcliffe, Horwich, near Bolton.

Mr. JAMES ROBERT HARK, Mining Student, 92, Market Street, Hindley, near Wigan.

The Annual Report of the Council was read as follows:—

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ANNUAL REPORT OF THE COUNCIL, 1903-1904.

At this, the sixty-sixth Annual Meeting, the Council have pleasure in presenting their report on the proceedings of the Society during the year, and also in congratulating the members upon the satisfactory progress which has been made.

The membership of the Society has been considerably augmented during the year, no fewer than 30 new names having been added to the list. Against this, must be taken the inevitable losses by death and resignation amounting to 10, of which death claims 3. The register now comprizes 8 honorary, 11 life and 228 ordinary members, making a total of 247, being a net increase of 20 over the last year.

Of the deceased members, Mr. James Tonge will be remembered as a past-president and for some years one of the Society's honorary secretaries, and also for the sustained interest which he evinced in the work of the Society for many years; the others being Messrs. F. W. Scott and J. Evans.

The Treasurer's statement of accounts shows that the financial position of the Society is thoroughly satisfactory.

The Annual Meeting, 8 Ordinary Meetings and 1 Special Meeting were held in the Society's rooms, when valuable papers were read and discussed, some of them being of more than a local interest. Also, following the practice of recent years, an extra meeting was held in the Museum Buildings, Owens College, on February 19th, when an address, with lantern illustrations, was given by Mr. George H. Winstanley, on "The Mechanical Equipment of Collieries." The attendances have been very satisfactory.

In his Presidential Address, Col. George H. Hollingworth, F.G.S., re-introduced the question of federating the Society with The Institution of Mining Engineers; he also referred to the valuable work being carried on by the Society, and named a variety of subjects as suitable for papers, such as the working of mines at great depths, the correlation of the upper series of the Lancashire Coal-measures, coal-cutting by machines, and the application of mechanical appliances generally. The majority of these subjects have been discussed.

During the session, valuable papers and short communications have been read before the Society and published in its *Transactions*, on geological subjects by Mr. W. J. Sutton,

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Mr. Henry Hall, H.M.I.M., I.S.O., Mr. Joseph Dickinson, F.G.S., Mr. Herbert Bolton, F.R.S.E., Mr. Walter Baldwin, F.G.S., Prof. W. Boyd Dawkins, M.A., D.Sc., F.R.S., etc., Mr. J. Barnes, F.G.S., Mr. John Gerrard, H.M.I.M. and Mr. B. Hobson, M.Sc.; and on mining subjects by Mr. W. H. Johnson, B.Sc., Mr. Alfred J. Tonge, Mr. George H. Winstanley, F.G.S., Mr. Maurice Georgi, M.Inst.M.E., etc., Mr. James Tonge, F.G.S., Mr. W. H. Jones, Mr. Joseph Dickinson, F.G.S., Mr. John Rigby, J.P., and Mr. Philip C. Pope. The late Mr. James Tonge read a report, as the Society's Delegate to the meeting of the British Association for the Advancement of Science, held at Southport in September, 1903.

The complete list of the papers and other contributions is as follows:—

"A Carboniferous Air-breather." By Mr. Walter Baldwin, F.G.S.

"The Palæontology of the Lancashire Coal-measures, Parts I., II. and III." By Mr. Herbert Bolton, F.R.S.E.

"The Physical and Chemical Properties of the So-called Coal-deposit Exhibited by Mr. Henry Hall, I.S.O." By Prof. W. Boyd Dawkins, D.Sc., M.A., etc., and Mr. Jonathan Barnes, F.G.S.

"Eruption attributed to a Vacuum." By Mr. Joseph Dickinson, F.G.S.

"Tapping Fluids under Pressure." By Mr. Joseph Dickinson, F.G.S.

"The Cohesion of Strata overcome by Pressure and Other Causes." By Mr. Joseph Dickinson, F.G.S.

"The Application of Electricity for Winding and other Colliery Purposes." By Mr. Maurice Georgi.

"Fossils found above the Bradford Four-feet Coal at Bradford Colliery, near Manchester." By Mr. John Gerrard, H.M. Inspector of Mines.

"Abraded Coal." By Mr. Henry Hall, I.S.O., H.M. Inspector of Mines.

"A Glacial Boulder from Red Bank, Hanging Ditch, Manchester." By Mr. Bernard Hobson, M.Sc., F.G.S.

"Presidential Address." By Col. George H. Hollingworth, F.G.S.

"A Machine for Testing Miners' Safety-lamps." By Mr. W. H. Johnson, B.Sc.

"Practical Comparisons of Continuous-current and Polyphase Electric Systems, as applied to British Collieries." By Messrs. Philip C. Pope and Norman D. Cameron.

"Outburst from Duncrue Old Rock-salt Mine, after being Tapped for Brine." By Mr. John Rigby.

"Geology and Mining of Vancouver Island." By Mr. W. J. Sutton.

"Coal-cutting by Machinery." By Mr. A. J. Tonge.

"Report of the Delegate to the Conference of Delegates of Corresponding Societies of the British Association for the Advancement of Science, Southport, 1903." By Mr. James Tonge.

"Education in Coal-mining." By Mr. J. Tonge, Jun., F.G.S.

"Mining Examinations, with Special Reference to the Board of Education Examination in Mining." By Mr. George H. Winstanley, F.G.S.

"The Mechanical Equipment of Collieries." By Mr. George H. Winstanley, F.G.S.

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Numerous specimens of rare fossils were exhibited by Mr. John Gerrard, H.M.I.M., and Mr. Walter Baldwin, F.G.S.

In addition to the usual increase of the Library by exchanges, which continue to be received, special mention may be made of the donation to the Society of a large number of volumes of the proceedings of the Institution of Civil Engineers by Lieut.-Col. Sir Lees Knowles, Bart., M.P., which materially add to the interest and value of the Library.

The Council have pleasure in congratulating Lieut.-Col. Sir Lees Knowles, Bart., M.P., a member and co-trustee of the Society, who has had conferred upon him the dignity of a baronetcy.

The Council, having been assured that it was the desire of a large number of the members that the question of federating the Society with The Institution of Mining Engineers should be reconsidered, this important subject was carefully investigated, and having examined the general scheme of the Institution, they concluded that in a large measure it was in accord with the Society's objects and that the Society might be affiliated with The Institution of Mining Engineers with mutual advantage. After issuing a lengthy report prepared by Messrs. Hollingworth, Gerrard, Mitton and Saint for their information, fully explaining the subject and canvassing the members thereon, and finding that a large majority of the votes were given in favour of the proposed change, your Council authorized the President to make formal application, on behalf of the Society to join The Institution of Mining Engineers, and the application was cordially acceded to.

It seems desirable to point out for the information of the members that The Institution of Mining Engineers was founded on July 1st, 1889, its principal object being "the advancement and encouragement of the sciences of mining, metallurgy, engineering and their allied industries." It now comprizes the following mining societies, arranged alphabetically, namely:—The Manchester Geological and Mining Society; the Midland Counties Institution of Engineers; the Midland Institution of Mining, Civil and Mechanical Engineers; the Mining Institute of Scotland; the North of England Institute of Mining and Mechanical Engineers; the North Staffordshire Institute of Mining and Mechanical Engineers; and the

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South Staffordshire and East Worcestershire Institute of Mining Engineers.

Under the constitution of The Institution of Mining Engineers, a general scheme has been evolved, which, whilst preserving the corporate individuality of each society, enables mining engineering to take the highest rank as a scientific profession and its members to be more highly appreciated. It affords a means of communication between the various mining districts of Great Britain, the Colonies and India, and of enabling each to acquaint itself with the superior or peculiar practices of others. It undertakes the sole publication of the proceedings of the federated societies, and a mass of useful knowledge is thus collected together and rendered easy for reference. It also publishes separately the *Transactions* of the respective societies, to which non-federated members belong, a copy of which is supplied to each non-federated member. For each non-federated member the local society pays 10s. per annum to cover the cost of publication.

The respective societies pay for each federated member, who receives a copy of the *Transactions*, a sum of, at present, 19s. per annum; or such other sum per annum as the Council may from time to time determine. The members therefore receive the *Transactions* of all the federated societies for one subscription, which would have cost about £11 per annum prior to the formation of The Institution of Mining Engineers. This Society is responsible for the payment in respect of its members of the annual subscriptions to the Institution.

It is worthy of note that, although federated, each society preserves its local independence, and retains full control over its possessions and proceedings, future publications in the *Transactions* of The Institution of Mining Engineers being excepted.

The interests of those members who do not become members of The Institution of Mining Engineers are not affected by the change. They retain all their privileges, and will continue to receive the *Transactions* of the Society as hitherto. Their annual subscription remains as before, namely, £1 each.

Members can become members of The Institution of Mining Engineers only through one or other of the federated societies. The classification of membership and the annual subscriptions

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to this Society which, with the consent of the members, have been decided upon are as follows:—Members, £2 2s.; Associate Members, £2 2s.; Associates, £1 5s.; and Students, £1 5s.; for which each federated member will receive a copy of the *Transactions* of the whole of the federated societies, together with those of the General Meetings held in London and elsewhere, and 100 pages of abstracts from foreign publications of great interest to geologists and mining and mechanical engineers; and now comprized in two annual volumes of about 800 or 900 pages each, which will probably be increased by the inclusion of the proceedings of this Society.

Each member is entitled to attend and take part in the meetings of the federated societies respectively in addition to the three general meetings already mentioned.

It is, therefore, anticipated that, under the new conditions, the influence of the Society will be more effective than heretofore, as it now affords its members a valuable medium of closer intercourse with a large number of societies having objects similar to its own.

The Rules of the Society have been altered and amended so as to conform with the general practice, and also so as to harmonize them with those of The Institution of Mining Engineers. The new rules were duly submitted to the members at the special meeting held on September 9th last, and were unanimously adopted.

Three excursions were arranged during the Session. There was a large attendance on each occasion. The first excursion was made jointly with the British Society of Mining Students to the Westinghouse electrical engineering works at Trafford Park, Manchester, under the leadership of Mr. Philip C. Pope. The second excursion took place on June 11th, with the kind permission of Mr. Edward Sandeman, M.Inst.C.E., the chief engineer to the Derwent Valley Water Board, to view the sites of the reservoirs now in course of construction near Bamford, under the leadership of Prof. W. Boyd Dawkins and Messrs. Winser and Richards, resident engineers. The third excursion took place on August 13th to Sparth Bottoms, Rochdale, under the leadership of Mr. W. H. Sutcliffe, where the members examined the *Carbonicola-acuta* and other beds, where so many valuable fossils have been recently discovered; and afterwards,

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under the leadership of Mr. S. S. Platt, inspected two new bridges built of ferro-concrete over the river Spodden, the new car-shed, and the Town Hall, Rochdale. An account of each of these excursions has been printed, immediately following this report, in the *Transactions*.

The Council, in reviewing the work of the past year, are deeply sensible of the debt which the general body of members owe to those gentlemen who have assisted in promoting the objects of the Society, to whom their best thanks are hereby tendered. The Council also express the hope that the increased activity shown may be sustained, and may be an incentive to those members who have not yet been induced to take a personal share in the Society's operations.

The appreciation of the work of the Society is shown by the increasing attendances at its meetings and the larger number of applications which are now received for copies of individual papers. The Council, therefore, confidently ask for the hearty co-operation of the members generally in enlarging the usefulness of the Society.

In conclusion, the Council would urge that a special effort be made by the members to bring to the notice of their friends interested in geology and mining and mechanical engineering, the advantages now afforded by the Society, with the object of inducing them to become members or subscribers. More frequent use of their privileges might be made by members by introducing visitors, especially those who are interested in the discussions, and thus they would aid in advancing the objects of the Society, namely, the collection and diffusion of knowledge respecting geology and mining, and also materially assist in maintaining the high reputation of the Society as a valuable scientific organization of Lancashire and the adjoining counties.

The following Statement of Accounts was presented by the Honorary Treasurer:—

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DR. THE TREASURER IN ACCOUNT WITH THE MANCHESTER GEOLOGICAL AND MINING SOCIETY, FOR THE YEAR ENDING SEPTEMBER 30TH, 1904. CR.

	£	s.	d.		£	s.	d.
Sept. 30th, 1903.				Sept. 30th, 1904.			
To Balance in the bank	99	19	8	By Rent, wages, and expenses of rooms	130	10	0
,, ,, in Secretary's hands	0	14	3½	,, Printing *Transactions*	66	0	9
Sept. 30th, 1904.				,, Circulars and stationery	18	3	0½
To Members' subscriptions :—				,, Postages, etc.	22	19	11
Current 188 10 0				,, Reporters	9	9	0
Arrears 19 10 0				,, Library	3	4	10
208 0 0				,, Sundry expenses	6	16	9
To Dividends :—				,, Balance in bank	105	12	6
Birkenhead Railway 22 17 6				,, ,, Secretary's hands...	6	14	4
Lancashire and Yorkshire Railway 20 19 3							
43 16 9							
To Bank interest	2	1	8				
To Hire of rooms	7	2	0				
To Sales of *Transactions*	6	16	0				
To Sundries	1	0	9				
	£369	11	1½		£369	11	1½

DR. LIBRARY ACCOUNT. CR.

	£	s.	d.		£	s.	d.
Sept. 30th, 1903.				Sept. 30th, 1904.			
To Balance brought forward	7	11	3	By Atlas	1	15	0
,, John Gerrard, subscription	2	2	0	,, Books	3	2	10
,, A. Dury Mitton, Do.	1	0	0	,, Books	2	1	6
,, L. B. Wells, Do.	1	0	0	,, Balance, carried forward	4	17	5
,, Bank interest	0	3	6				
	£11	16	9		£11	16	9

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Balance Sheet, September 30th, 1904.

Liabilities.	£	s.	d.
Outstanding accounts :—			
J. E. Cornish	0	4	6
Manchester Corporation	0	9	2
J. Roberts & Son, say	60	0	0
Reporter	1	1	0
	61	14	8
Balance in favour of the Society	1,955	9	7
	£2,017	4	3

Assets.	£	s.	d.
£600 Birkenhead Railway Consolidated Preference Guaranteed Stock, at £121 per cent. ...	726	0	0
£733 Lancashire and Yorkshire Railway 3 per cent. Consolidated Preference Stock, at £86½ per cent.	634	0	0
Library and furniture	500	0	0
Cash in bank	105	12	6
,, in Secretary's hands	6	14	4
Arrears of subscriptions, £73, say	40	0	0
Balance of Library Fund	4	17	5
	£2,017	4	3

The Investments of the Society consist of £600 Birkenhead Railway Consolidated Preference Guaranteed Stock, and £733 Lancashire and Yorkshire Railway 3 per cent. Consolidated Preference Stock. The certificates for these are deposited at the Williams Deacon and Manchester and Salford Bank, St. Ann's Street, Manchester, and were inspected by us on October 11th, 1904.

Audited and found correct, October 11th, 1904.

Geo. H. Hollingworth,
Honorary Treasurer.

Jno. Barnes,
G. H. Winstanley, } *Auditors.*

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The Report of the Council and the Treasurer's Statement of Accounts were unanimously adopted.

ELECTION OF OFFICERS, 1904-1905.

The following officers were unanimously elected for the ensuing year:—

PRESIDENT:

Mr. JOHN GERRARD, H.M. Inspector of Mines.

VICE-PRESIDENTS:

Mr. JOHN ASHWORTH. | Mr. GEORGE B. HARRISON. | Mr. SYDNEY A. SMITH.
Mr. ALFRED J. TONGE.

HONORARY TREASURER: Col. GEORGE H. HOLLINGWORTH.

HONORARY SECRETARY: Mr. WILLIAM SAINT.

OTHER MEMBERS OF THE COUNCIL:

Mr. H. S. ATHERTON.	Mr. A. DURY MITTON.	Mr. CHARLES PILKINGTON.
Mr. HENRY BRAMALL.	Mr. W. OLLERENSHAW.	Mr. JOHN ROBINSON.
Mr. G. W. MACALPINE.	Mr. GEORGE PEACE.	Mr. JAMES TONGE.
Mr. D. H. F. MATHEWS.	Mr. WILLIAM PICKSTONE.	Mr. LIONEL B. WELLS.

HONORARY AUDITORS:

Mr. JONATHAN BARNES. | Mr. GEORGE H. WINSTANLEY.

Col. HOLLINGWORTH said that, his year of office as President having expired, he desired to thank the members for their support during the session, which he thought had been a busy and satisfactory one.

Mr. JOHN ROBINSON said that he had much pleasure in proposing a hearty vote of thanks to Col. Hollingworth for his efficient services as President during the past year. He had done much to further the best interests of the Society, which was now united with The Institution of Mining Engineers.

Mr. H. STANLEY ATHERTON seconded the proposal, which was carried by acclamation.

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The complete list of the Council for the ensuing year is as follows:—

President:

Mr. JOHN GERRARD, H.M.I.M.

Vice-Presidents:

Mr. SYDNEY A. SMITH, Assoc. M. Inst. C.E.

Mr. JOHN ASHWORTH, C.E. | Mr. ALFRED J. TONGE, F.G.S.

Mr. GEO. B. HARRISON, H.M.I.M.

Vice-Presidents (*ex officio*):

Mr. JOSEPH DICKINSON, F.G.S.

Prof. W. BOYD DAWKINS, M.A., D.Sc., F.R.S., F.G.S.

Mr. R. CLIFFORD SMITH, F.G.S.

The Right Hon. the EARL OF CRAWFORD AND BALCARRES.

Lord SHUTTLEWORTH OF GAWTHORPE.

Mr. EDWARD PILKINGTON, J.P. | Mr. ROBERT WINSTANLEY, C.E.

Mr. HENRY HALL, I.S.O., H.M.I.M. | Mr. JOHN S. BURROWS, F.G.S.

Mr. WM. SAINT, H.M.I.M. | Mr. MARK STIRRUP, F.G.S.

Mr. WM. WATTS, F.G.S. | Mr. JOHN RIDYARD, F.G.S.

Mr. W. S. BARRETT, J.P.

Mr. G. C. GREENWELL, M. Inst. C.E., F.G.S.

Mr. JONATHAN BARNES, F.G.S.

Col. GEO. H. HOLLINGWORTH, F.G.S.

Honorary Treasurer:

Col. GEO. H. HOLLINGWORTH, F.G.S.

Honorary Secretary:

Mr. WILLIAM SAINT, H.M.I.M.

Other Members of the Council:

Mr. H. STANLEY ATHERTON. | Mr. D. H. F. MATHEWS, H.M.I.M.

Mr. HENRY BRAMALL, M. Inst. C.E. | Mr. G. W. MACALPINE

Mr. A. DURY MITTON, Assoc. M. Inst. C.E.

Mr. W. OLLERENSHAW. | Mr. GEO. PEACE.

Mr. CHAS. PILKINGTON. | Mr. JOHN ROBINSON.

Mr. WILLIAM PICKSTONE. | Mr. JAMES TONGE, F.G.S.

Mr. LIONEL B. WELLS, M. Inst. C.E.

Honorary Auditors:

Mr. JONATHAN BARNES, F.G.S.

Mr. GEORGE H. WINSTANLEY, F.G.S.

Trustees:

Mr. JOSEPH DICKINSON, F.G.S.

Lieut.-Col. Sir LEES KNOWLES, BART., M.A., L.L.M., F.G.S., F.Z.S., D.L., M.P.

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New Members:

Aboksamy, M. R.	Dixon, Wm. B.	Munroe, Martin
Bentley, George	Glover, R. B.	Nicholson, Jas., Jr.
Bradshaw, Hubert	Graham, Geo.	Ormand, Percy
Buckley, C. A.	Hatton, G. P.	Pope, Philip C.
Constantine, E. G.	Higson, Peter	Spackman, Chas.
Campbell, H. H.	Gillott, J. W.	Ritson, T. F.
Collier. Rev. E. C., M.A	Hollingworth, Henry	Robinson, Fred.
Davies, G. M.	Humphris, Henry	Turner, Charles
Dickson, James	Johnson, W. H., B.Sc.	Walker, Howard J.
Dixon, Walter	Macalpine, G. L., B.Sc.	Wood, Thomas

Members Resigned:

Atkinson, W. N.	Holroyd, W. F.	Smethurst, W. A.
Champ, H.	Laverick, J. H. W.	Wall, Capt. A.
Glover, B. B.	Lea, W.	

Members Deceased:

Evans, J.	Scott, F. W.	Tonge, James

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MANCHESTER GEOLOGICAL AND MINING SOCIETY.

EXCURSION MEETING,
JANUARY 22ND, 1904.

The members visited the works of the British Westinghouse Electric and Manufacturing Company, Limited, at Trafford Park, Manchester, accompanied by members of the British Society of Mining Students.

TRAFFORD PARK WORKS OF THE BRITISH WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY, LIMITED.

A decade ago, Trafford Park, the ancestral home of the De Trafford family, on the outskirts of Manchester, formed a splendid example of an English demesne, but its proximity to the Manchester Ship Canal was fatal to its continuance as a residential estate. The result has been that works of every description have sprung up on all sides, and amongst these is the establishment of the British Westinghouse Electric and Manufacturing Company, Limited. The buildings were commenced in 1901 and were carried through at record speed, the work being finished between 12 and 18 months afterwards. Some idea of the size may be gathered from the fact that some 11,000,000 bricks, 9,000,000 square feet of timber, 300,000 square feet of glass-roofing and 17,000 tons of steel were used in their erection, giving employment to nearly 4,000 workmen.

The office-building, comprizing the various managerial, engineering and commercial departments, etc., is 250 feet long, 50 feet deep, 6 storeys high, and covers an area of nearly $1\frac{3}{4}$ acres.

The large machine-shop, 430 feet wide and about 1,000 feet long, is divided into five aisles or bays. There are separate malleable-iron, steel- and brass-foundries, a large forge, pattern-

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shops, box-factory, and various smaller shops. Altogether, the buildings cover more than one-third of the total ground-area, and an extensive railway network, comprizing some 10 miles of track, serves for the conveyance of patterns, castings, and partly or wholly finished material from one point to another, this network being also connected with the local railways at two or three points.

The number of hands at present employed is between 4,000 and 5,000, and many of them reside in the newly-built cottages and houses, which, together with an hotel, clubhouse, etc., have been erected near the works.

The machinery is electrically driven, the generating plant for supplying motive power and light being larger than is found in many towns.

Practically every machine and appliance used in heavy electrical engineering is built or manufactured at these works, including steam-turbines for driving electrical generators or any other machinery, steam-engines and gas-engines. Four Westinghouse steam-turbo-electric generators, each having a capacity of nearly 7,000 horsepower, have been supplied to the Neasden power-station of the Metropolitan Railway Company, London; and similar machines of 60,000 brake-horsepower are being erected at the Chelsea power-station of the London Underground Electric Railways, Limited.

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MANCHESTER GEOLOGICAL AND MINING SOCIETY.

EXCURSION MEETING,
JUNE 11TH, 1904.

The members visited the sites of the Howden and Derwent reservoirs respectively, near Bamford, of the Derwent Valley Water Board, under the leadership of Prof. W. Boyd Dawkins, and Messrs. Winser and Richards, resident engineers.

DERWENT VALLEY WATER-SCHEME.

The Derwent Valley water-scheme is for the supply of water to the towns of Leicester, Derby, Sheffield and Nottingham, and the counties of Derby and Nottingham. The scheme includes the construction of (*a*) five reservoirs for impounding the waters of the rivers Derwent and Ashop; (*b*) about 100 miles of aqueduct for distributing the water to the various authorities; (*c*) about 20 acres of filter-beds at Bamford; and (*d*) a service-reservoir at Ambergate. The ultimate daily supply of water to each authority will be approximately as follows:—Leicester, 9,800,000 gallons; Derby, 6,800,000 gallons; Sheffield, 6,800,000 gallons; Nottingham, 3,900,000 gallons; Derbyshire, 5,000,000 gallons; and Nottinghamshire until 1930, 1,000,000 gallons; a total of 33,300,000 gallons.

There will be three reservoirs on the river Derwent (the Howden, Derwent and Bamford reservoirs); and two reservoirs on the river Ashop (the Haglee and Ashopton reservoirs).

For the first instalment, only the Howden and Derwent reservoirs will be required, and these are now in course of construction. Howden is the up-stream reservoir.

The foundations of both dams are in the Yoredale series of the Carboniferous system. The foundation of the Howden dam had been laid at a depth of 68 feet below the river-bed. A narrow trench, 6 feet wide, on the north side of the foundation

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had been sunk to a depth of 88 feet below the river-bed, and was being filled with concrete to prevent water from percolating through the shales under the main body of the dam. The trench for the Derwent dam was about 60 feet deep, and was being cut by means of channelling-machines.

Prof. W. Boyd Dawkins said that the two very remarkable examples of folding and faulting shown in the puddle-trenches of the two reservoirs were caused by relaxation of pressure, brought about by the removal of the rocks during the excavation of the valley by the river. The foldings, strongly marked at the surface, disappear at a depth of 90 feet in the upper, and at a depth of 60 feet in the lower, of the two puddle-trenches. In both cases, the thicker beds of sandstone below are continuous, and offer a good foundation for the masonry-dam. In both cases, too, the folds are distinguished by small faults from the unfolded rock in the sides of the valley.

He (Prof. Boyd Dawkins) had observed a like superficial folding of the strata at the bottom of valleys carved out of the shales and thin interbedded sandstones of the Millstone Grit and Yoredale rocks in several other places, such, for example, as Langsett reservoir, in the valley of the Little Don. He found, as a matter of experience, that these folds were superficial, and disappeared as the puddle-trench was carried down from the surface. It was therefore obvious that they were not due to deep-seated movements of compression resulting from the contraction of the earth. They were due to the relaxation of pressure caused by the removal of the rock from the area of the valley, and were analagous, in every respect, to the "creep" in coal-workings caused by the removal of the coal, in consequence of which the surrounding strata crush down into the area of relaxed pressure and ultimately fill it up. This phenomenon may be studied in any coal-pit where there is a pressure of more than 1,000 feet of rock.

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MANCHESTER GEOLOGICAL AND MINING SOCIETY.

EXCURSION MEETING,
AUGUST 13TH, 1904.

The members visited Sparth Bottoms, Rochdale, under the leadership of Mr. W. H. Sutcliffe, F.G.S., and examined the *Carbonicola-acuta* bed, and others, in a quarry where many valuable fossils have been discovered. They also inspected a large collection of fossils, etc., deposited in the Rochdale museum.

Afterwards, under the leadership of Mr. S. S. Platt, M.Inst. C.E., F.G.S., the borough engineer, the members inspected two new bridges over the river Spodden and other works, constructed of Hennebique ferro-concrete, the new tramcar-shed, the interior of the Town Hall, etc.

SPARTH BOTTOMS QUARRY, ROCHDALE.

BY WALTER BALDWIN.

The Middle Coal-measures are repeatedly thrown in between Rochdale and Heywood by several large faults, which run north-west and south-east, and are probably of the same age. The Middle Coal-measures at Sparth have been brought in by one of these faults, which has its downthrow to the north-east. It starts in the Nayden valley, close to Greenbooth mill, near Norden, and runs by Cutgate, skirting the north-western border of the Rochdale cemetery, crosses the Manchester road about a mile from the Rochdale Town Hall, and is eventually lost in the Thornham district by reason of the thick deposits of drift, which have rendered our knowledge of the solid geology of that district so very imperfect.

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The Royley mine comprizes:—Coal, 2 feet 7 inches; fireclay, 4 inches; and coal, 1 foot 6 inches; a total of 4 feet 5 inches. It crops out under the new tramway-depôt in Mellor Street, close by Spotland Bridge; and passes round by the corner of Ashworth Street and Mount Street. The average dip for this district is about 1 in 9 to the south-west, although in some places the dip has undergone an alteration both in magnitude and direction.

The *Carbonicola-acuta* bed lies about 135 feet above the Royley mine. The Old Neddy seam was pierced when the shaft at Brimrod Wood was sunk, and it showed that the distance between the Old Neddy seam and the Royley seam was 260 feet.

Prestwichia rotundata has come from the highest beds, which are seen exposed.

Eoscorpius sparthensis was found 8 feet above the *Carbonicola-acuta* bed.

Euphoberia ferox came from the *Carbonicola-acuta* bed.

Spiroglyphus came from the same bed, and also occur at a higher horizon.

Belinurus lunatus (*Belinurus bellulus* of — König) was found in the *Carbonicola-acuta* bed.

Pygocephalus and *Strepsodus*-scales came from the same horizon as *Prestwichia*.

HENNEBIQUE FERRO-CONCRETE CONSTRUCTION.

By S. S. PLATT.

There seems a tendency for the universal reign of steel to be giving way somewhat to a return of masonry-construction, not to brick and stonework, but to an artificial stone, that is, concrete strengthened by steel: variously called "ferro-concrete," "concrete-steel," "armoured concrete," "fortified concrete," "reinforced concrete," and so forth, depending upon some variety in the method of union of the two materials of which it is composed.

Concrete is not a new constructional material, but it is comparatively weak when exposed to tensile strains. However, in

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combination with steel, in which the steel, in any form, is rigidly embedded in concrete, the concrete stiffens the steel, and the steel reinforces the concrete, thereby producing a constructional material of great value, economic adaptability and usefulness. An important consideration is that once properly made, the first cost is the only cost. A great advantage over steel-construction, which, if exposed to atmospheric influences, requires a constant outlay for maintenance.

In order to attain successful application of this combined constructional material, it is absolutely necessary that the work should be entrusted only to persons properly qualified to settle the proportions and distribution of the reinforcement; and the work must be carried out (under qualified supervision) by contractors experienced in this class of work. Any departure from, or non-observance of, the essentials of first-class work rapidly reduces the strength of this most valuable constructional material in a manner which cannot be determined by calculation.

(*a*) Two bridges carrying a new street over the river Spodden near Spotland Bridge, Rochdale. The special reason for adopting ferro-concrete construction arose from the abnormal difficulties due to the presence of colliery workings in the Royley mine, at a depth of from 30 to 40 feet below the river-level: the workings contain water which is being pumped and used for industrial purposes. To rest a bridge on ground so badly honeycombed would have been to court disaster. Ferro-concrete piles, 14 inches square, 40 to 60 feet deep (spaced approximately at 10 feet centres longitudinally and transversely) were placed in bore-holes through the colliery workings and driven at least 2½ feet into the solid stratum below. Upon these piles each of which was calculated to give a resistance equal to a dead load of over 90 tons, were built the abutments of the bridge. These bridges are the first, in this country, constructed of ferro-concrete from the foundations to the superstructure. They are also the first that have been built with slab-arches, that is, arches without ribs or beams.

(*b*) The covering of the river Roch, in the centre of the town, between the Rochdale and Wellington Bridges, so as to form a

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central open space for the distributing centre of the electric tramways of the borough and district, was also carried out in ferro-concrete, as it appeared to possess such advantages of economy in construction and maintenance (particularly with reference to the avoidance of the requirement of regularly painting the underside of a structure exposed to the gaseous emanations from a river largely used for industrial purposes), in place of the ordinary steel-decking construction.

The covering is about 300 feet long and 60 feet wide. It consists of a continuous slab of ferro-concrete, 6 inches thick, supported by main beams, 16 inches deep by 14 inches wide, spaced approximately 20 feet, from centres to centres, transversely and 13 feet, from centres to centres, in the longitudinal direction of the river. The main beams rest upon the old side-walls and two intermediate pillars; the secondary beams, 10 inches deep and 7 inches wide, spaced about 5 feet from centres to centres, support the slab between the main beams: the whole being built of ferro-concrete.

After completion, the above-described structures were tested by passing over them a load of 32 tons on a boiler-wagon, with a wheel-base measuring $8\frac{1}{2}$ feet by $6\frac{1}{2}$ feet, drawn by a traction-engine weighing 13 tons, and the footpaths were loaded up to 140 pounds per square foot. The maximum observed deflection was only about $\frac{1}{25}$ inch, and, shortly after the removal of the loads, the structures resumed their original position. These tests are considered very satisfactory.

The saving in initial cost was about 25 per cent. over the estimate for steel-construction.

The works were initiated by, and carried out under the superintendence of, the writer, with whom has been associated Mr. L. G. Mouchel, C.E., London.

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The entire Series of the Geological Survey Maps on the one-inch and six-inch scale, with Memoirs, of the Lancashire Coal Field, is now complete, and available for reference by the Members.

Catalogue of the Library, price 1s. 6d.

Mr. Dickinson's Chart of Coal Strata of South Lancashire may be had separately at 6d., or with the part containing the letterpress at 1s. each.

Application for Volumes or Parts of unbound Volumes of the Transactions to be addressed only to the Hon. Secretary, Queen's Chambers, 5, John Dalton Street, Manchester.

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PART II. VOL. XXIX.

TRANSACTIONS

OF THE

MANCHESTER GEOLOGICAL & MINING SOCIETY.

EDITED BY

THE HONORARY SECRETARY.

SESSION 1904-1905.

PUBLISHED AT THE ROOMS OF THE SOCIETY,
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JUN 6 1905

MANCHESTER GEOLOGICAL AND MINING SOCIETY.

ORDINARY MEETING,

HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS, 5, JOHN DALTON STREET, MANCHESTER, ON NOVEMBER 8TH, 1904.

MR. JOHN GERRARD, PRESIDENT, IN THE CHAIR.

The following gentlemen were elected, having been previously nominated:—

HONORARY MEMBERS—

MR. HERBERT BOLTON, F.R.S.E., Curator and Secretary, The Museum and Reference Library, Bristol.

MR. MARK STIRRUP, F.G.S., High Thorn, Stamford Road, Bowden, Cheshire.

MEMBERS—

MR. RONALD GORDON GRANT, Electrical and Mechanical Engineer, British Power Company, 5, Great George Street, Westminster, London, S.W.

MR. H. P. HARRIS, Mining Engineer, Brynmally Collieries, Wrexham.

MR. WARWICK GREY HODGE, Electrical and Mechanical Engineer, Halford Park Road, Lytham.

MR. JOHN EDWARD LANDLESS, Manager, Habergham Colliery, Burnley.

MR. DANIEL MORRISON, Civil and Mining Engineer, 41, John Dalton Street, Manchester.

MR. MONTAGUE BROWN MOUNTAIN, Mechanical and Electrical Engineer, Redcliffe House, Barton-on-Irwell, Manchester.

MR. THOMAS POWER. Owner and Manager, Commons Colliery, The Commons, Thurles, Ireland.

MR. GEORGE G. K. PREECE, Mechanical and Electrical Engineer, 134, Russell Street, Moss Side, Manchester.

MR. CECIL SYDNEY RAMSDEN, Civil and Mining Engineer, 42, Deansgate, Manchester.

MR. HAROLD RIGBY, B.Sc., Mining Engineer, Greville Lodge, Winsford, Cheshire.

MR. WILLIAM YOUNG, Manager, Slievardagh Collieries, Ballynonty, Thurles, Ireland.

STUDENT—

MR. FREDERICK NORMAN TONG, Spring Bank, Astley Bridge, Bolton.

The PRESIDENT (Mr. John Gerrard) read the following "Presidential Address":—

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PRESIDENTIAL ADDRESS.

By JOHN GERRARD, H.M. Inspector of Mines.

Colonel Hollingworth, in his inaugural address a year ago, after alluding to the change in the title of the Society, said: "I hope it will take further steps with a view of being in reality the Mining Institute for Lancashire, Cheshire, and the neighbourhood." One further step has been taken: we commence this Session conjoined with the other mining societies in England and Scotland as The Institution of Mining Engineers. We now stand in line with the 2,688 members of that Institution, and upon any question that may be referred our voices will be joined with theirs. We shall have the opportunity of meeting mining men from all parts. Our experience will be given to them, and theirs we shall receive. Last year 79 papers on mining and geology were circulated amongst the members. We shall be enabled to read all such papers and any that it may be desired can be discussed by this Society. Our individuality will be fully maintained, we shall have our own officers, our comfortable rooms, our excellent library, and the funds that we have accumulated will still be ours. No longer will the mining men of this coal-field have reason to forward subscriptions to Scotland, Newcastle-upon-Tyne, Yorkshire, the Midland counties or Staffordshire. Is it not now their duty to support their own Society? May the hope be expressed that during this coming year all will join us, and help to make the Society fully representative of this large and important coal-field.

Within the Lancashire and Cheshire coal-field it is stated that there are 400 mines, giving employment to 95,000 persons and producing 25,000,000 tons of minerals. If we could induce our neighbours in North Wales to come to us, the number of mines would be increased to 463, with 108,000 persons employed, and 28,000,000 tons of minerals raised. These figures indicate that a large number of persons should be interested in "the

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collection and diffusion of practical and theoretical knowledge respecting geology and mining." These were the objects desired when, in 1838, this Society was established. There can be no manner of doubt that implied therein was the further object to fully consider the prevention of accidents and loss of life in mining operations. Our records give proof of the excellent work done. It was in 1862 that the famous papers on the gases met with in coal-mines, the general principles of ventilation, and on the friction of air in mines, were read before this Society by Mr. John Job Atkinson, H.M. inspector of mines. Most of those prominently associated with mining, past and present, have freely contributed of their experience. Many names could be honourably mentioned, Messrs. William Peace, Andrew Knowles, Peter Higson, John Knowles and George C. Greenwell gave their full support; and one whom we all so much revere, who is stated to have started as a mining pupil so long ago as 1835, Mr. Joseph Dickinson, constant in his attendance, ever ready to draw upon his vast experience by contributing papers or joining in their discussion. Surely then, we may expect the mining men of Lancashire to follow these excellent examples.

With regard to geology, may we not appeal with confidence to those who have in the past done so much to extend its application, to continue the good work? The larger field, the contributions from other societies, we hope, will induce them to increase their interest and to extend their numbers. Probably no member of this Society more ardently represented geology than the late Mr. E. W. Binney. He is reported to have said in 1861, that "he had had hopes that the mining people of this district would have made this Society into something like a mining institute as well as a geological society," and now, after more than 40 years, Mr. Binney's hopes may be fulfilled. The opportunities afforded Mr. E. W. Binney, Prof. W. C. Williamson, Prof. W. Boyd Dawkins, Mr. Mark Stirrup, Mr. George Wild, and others, will be continued to their geological successors. We have been greatly gratified by the full support that Prof. W. Boyd Dawkins has given to the new movement. For 35 years he has been our geological mainstay, ever willing to help, delighted to display and describe the

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collections at the Museum of the Manchester University. Those who have visited other museums will agree that nowhere can be found a better collection of Coal-measure fossils, nowhere better stored, the order and facilities for viewing are perfect. Lancashire may well be proud of this Museum, the members of the Society and all others interested in coal-mining should continue to support it and send there the best specimens found in this coal-field.

There are many geological problems still unsolved, much geological work to be done. One of the most important questions affecting this district, upon which much depends, is that of the continuity of the Arley seam between Bolton and Manchester. Several explorations have failed to find the seam, in other places the seam is practically worthless. There may be an area within which the Arley seam was less richly deposited, entirely wanting, or, possibly after deposition, denuded. The change in the Arley seam from Wigan to St. Helens is well known; at the latter place it is known as the Little Delph. A careful mapping of the proved explorations, and the collection of the records, should now be made. A valuable paper might be contributed on this subject.

The extension of the coal-field in a southerly direction should be carefully watched. The boring at Astley has revealed what may prove to be a considerable extent of Coal-measures above the Worsley Four-feet seam. The proposed sinkings at Astley may enable a fuller examination to be made. The proving of the Mountain mines in the Wigan district cannot be long deferred. Then we shall know what changes have taken place in the Mountain mines from crop to deep.

There is much to be done as regards correlating the seams in the west and the east. Although there are many changes in the character of the seams, and their relative distances apart, on the west side of Manchester the seams are well correlated. But on comparing the seams found to the east of Manchester with those to the west, great differences are seen, and practically the problem is unsolved. The Mountain mines are clearly defined at Billinge on the extreme west, as at Littleborough on the extreme east. The Arley seam is at Rochdale, Heywood and Burnley on the east, as at Westhoughton, Ince and Wigan on the west.

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For 60 years, geologists have been puzzled as to the identity of the coal-seams at Bradford, Manchester. The sinking of the new shaft to a depth a little short of 2,700 feet should help to clear the situation. The strata ought to be carefully examined and the fossils collected.

In North Staffordshire, several marine beds have been located in the Middle Coal-measures, and also in Derbyshire. In Lancashire, only one has been clearly defined, the one found by that excellent geologist, Mr. George Wild, at Ashton Moss colliery, said to be about 750 feet above the Great mine. If the Great mine corresponds to the Crumbouke or Ince Four-feet seam, that marine bed is high up in the Middle Coal-measures. On the table are several specimens of marine shells, *Orthoceras*, *Pecten*, etc., found at Victoria colliery, Standish, probably near to the Arley mine. This is clearly a second marine bed, and careful examination of the strata near to the Arley mine may lead to this bed being found in other places. On the table is a specimen of *Pecten*, found above the Black Shale or Silkstone seam in Derbyshire by Mr. Walcot Gibson.

From a mining point of view, the Lancashire coal-field has associated therewith three especial features: steep inclinations, thin seams and great depth.

The greatest inclination is probably at Moston colliery, ranging from 40 degrees (in one place 51 degrees) to 20 degrees, or from 1 in $1\frac{1}{4}$ to 1 in $2\frac{3}{4}$. At a number of collieries, extending from Ashton-under-Lyne to Pendleton and Clifton, and again at St. Helens, the dip varies from 1 in $2\frac{1}{2}$ to 1 in $3\frac{1}{2}$. The inclination of the seams may be associated with the large faults which traverse this coal-field, the Irwell valley fault having a throw of 3,000 feet, and other faults of 1,800 feet, 1,500 feet and 1,200 feet have been proved. It will be admitted that the working of these steep seams involves greater difficulties and increased cost, and greater danger to the workers.

Probably in no coal-field, except Somerset, are thinner seams worked. Billinge, Bacup, Burnley, Accrington, Blackburn, Chorley, Rivington, Rochdale and Littleborough produce coal from the Mountain-mine series, from seams less than a foot to something over 2 feet thick.

At Pendleton colliery, coal is being worked at a depth of

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3,483 feet from the surface, a greater depth than elsewhere in Great Britain. For some years coal was wound at Ashton Moss colliery a vertical distance of 2,820 feet, and is now being raised from a depth of 2,268 feet. At Bradford colliery, a shaft is being sunk to a depth of 2,670 feet. The depth to the Arley mine at the proposed Astley colliery will probably be 3,400 feet. It will readily be seen that if the Rams mine at Pendleton corresponds to the Furnace mine at Ince, the depth to the underlying seams will be very considerable. A valuable paper would be one which mapped the area of deep coal in Lancashire and gave detailed information as to the probable depths of the seams. It is rather odd that only one paper has been contributed to this Society on deep mining: in 1870, Mr. John Knowles gave a full account of the working at depth at Pendleton colliery.

Probably the most important factor in deep mining is that of temperature. The deeper we go into the earth, the higher is the temperature. The ratio of increase in Lancashire may be said to vary from 1° Fahr. in 60 feet, to 1° Fahr. in 80 feet. At Pendleton colliery, the highest ascertained temperature in the working faces approaches to 94° Fahr. The depth at the shaft is 1,545 feet; an engine-plane, driven along the line of dip, has already been carried 6,000 feet from the shaft, and further extension is possible. The dip is about 1 in 3½.

Personal observations in the deepest known coal-mine, situate in Belgium, have proved that at a depth of 3,773 feet from the surface the highest temperature is 104° Fahr. In this mine, as at Pendleton, the air is remarkably dry. In the Belgian colliery, the dry bulb registered 104° Fahr., the wet bulb 84° Fahr., or 38 per cent. of humidity only. In Pendleton colliery, the dry bulb registered 93·3° Fahr., the wet bulb 79·7° Fahr., or 49½ per cent. of humidity. So far, practically, that which has been depended upon to cool the high temperature of the strata is ventilation. At Pendleton, it is true that haulage-engines, worked by compressed air, discharge small volumes of cool air, but the effect has been proved to be purely local.

Upon two points connected with deep mining papers might be contributed:—The effect of large volumes of fire-damp

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evolved from a pronounced fiery seam, and the effect of chemical action in coal-seams peculiarly liable to spontaneous combustion. Upon these points it is interesting to find that in 1865, Mr. E. W. Binney, in a paper contributed to the Manchester Geological Society on some of its objects, stated that "the expansion of fire-damp, when it escapes from the coal, has a considerable cooling effect, and has not yet received that attention which it deserves. On the other hand, the heat generated by the decomposition of sulphides of iron is seldom noticed in the observations on temperature." Sometime about 1879, Sir Lindsay Wood made interesting experiments on the pressure of fire-damp contained within coal-seams. It is well known that high temperatures are attained in working the Doe mine, at not inconsiderable depth. This seam is exceptionally liable to spontaneous combustion.

When greater depths are reached and higher temperatures attained, engineers will be called upon to experiment with a view to artificial cooling. The use of water is open to two objections; water introduced into a deep mine would require to be pumped out, and the saturation of the air greatly reduces the capacity of the men for work.

A visit to the great Simplon tunnel has given me a personal experience of the inconvenience of cooling the air by water. This is a railway-tunnel piercing the Alps, one entrance being at Brigue in Switzerland and the other at Iselle in Italy. The total length of the tunnel will be over 12 miles, and the cost will exceed £3,000,000. About 4,000 men have been employed on the Swiss side and about 6,000 on the Italian side. At the time of my visit, in May, 1904, the tunnel had been driven about 6 miles from the Swiss side. My observations gave the highest temperature in the air, 107° Fahr.; and where men were employed enlarging and putting in masonry, 97° Fahr. The dry and wet bulbs both registered the same, the air was, therefore, fully saturated. At seven or eight points, water was discharged from pipes in the form of spray. Various arrangements for spraying had been tried. The water-pipes were covered with insulating material (3 inches of charcoal) to keep the water cool, and the water was under a pressure of 1,500 pounds to the square inch. The fresh-won rock was cooled by

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water. Air is forced into one tunnel by two powerful fans, and returns by the main parallel tunnel. About 60,000 cubic feet of air per minute pass through the tunnels.

I was greatly pleased to see the excellent arrangements for the care of the workers: There is a convenient hospital, with a staff of nurses and attendants, well away from the works, with its outlook on the beautiful snowclad Alps. My train took in two attendants with all the necessary requirements to relieve 3 men injured by a fall of rock, where the main tunnel was being enlarged. A telephonic summons brought relief to the sufferers within half-an-hour of the accident. There are dressing-halls, equipped with hot and cold shower-baths, so that the workers can take off their working clothes to be dried, wash themselves, and put on dry clothes to go to their homes. Only about 10 per cent. of the men do not avail themselves of these arrangements. There are canteens, where well-cooked meals and pure, wholesome wine may be obtained at merely nominal prices—9d. a day for three meals: first meal: coffee, milk, sugar, bread, cheese; second meal: soup, meat, vegetables, salad, bread; third meal: thick soup and bread; and sleeping accommodation at 2d. per night for those requiring it.

The last Royal Coal Commission fixed 4,000 feet as the depth down to which our coal-resources were available. If the present Royal Commission adhere to that depth, as being the practicable depth at which coal may be worked, this conclusion will probably receive general approval, and it will enable a comparison to be made between the estimates of this Royal Commission and those of the last. Some people will wish to see a delineation of where deep coal may be found, with details as to the amount of coal between 4,000 feet and a deeper point.

It would, in a short address, be hardly possible to deal with the progress made in mining, or to attempt to suggest the subjects upon which papers might be contributed to this Society. Two suggestions, however, may be made: a small committee might be appointed to make observations in deep sinkings and in deep mines, in order that the best form of instrument be used, in the best manner, and to secure uniformity in the method of taking temperatures; another small committee might be appointed to

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watch the borings, excavations and sinkings in the Upper Coal-measures. If these committees made an annual report we should have a continuous record of progress in deep mining, and a collection of information bearing upon the resources of the coal-field.

There has been marked progress in all the branches of mining, in sinking, methods of working coal, ventilation, lighting, the use of explosives and appliances for breaking down coal, haulage, banking arrangements, and sorting and cleaning of coal. It is equally certain that further improvements will be made. We have had recently valuable papers upon the application of electricity and the cutting of coal by machinery. It may be suggested that a paper on the use of compressed air would be welcomed, and that there is room for considerable improvement in the appliances for drilling holes in sinking pits, tunnels or cross-measure drifts. Much progress has been made on the Continent in this direction.

Mining operations offer a wide field for the application of electricity. If the fact be fully recognized that its use has introduced two new dangers, electrocution and the danger of fires and explosions of fire-damp, there may be, on the one hand, greater care taken by users, and, on the other hand, continued efforts by electrical engineers to prevent those dangers from arising. We have had two fatal cases from shock in Lancashire, one from contact with a defective switch-board, the other from contact with a defective cable; and we have had one very disastrous fire established by a defective cable. From this exhibited piece of repaired cable and the photographs, it will be obvious to you that electric cables should be repaired in a proper manner. It is extremely foolish to repair a broken electric cable in the manner that a broken signal-cord would be repaired. It should further be clearly understood that the danger of electricity is not only associated with high pressures; under certain conditions, and they may be ordinary mining conditions, low pressures prove fatal.

In an address given four years ago it was shown that, by taking note of the large increase in the number of persons employed in mining operations, the loss of life is very much less than when mining legislation was first applied. Shortly, it may be stated that mining is now 3½ times safer than at that

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TABLE I.—SEPARATE FATAL ACCIDENTS IN AND ABOUT THE MINES OF GREAT BRITAIN AND IRELAND, UNDER THE COAL-MINES REGULATION ACTS.

PERIODS.	Explosions of Fire-damp or Coal-dust.	Falls of Roof and Side.	Shafts.	Miscellaneous Belowground.	On Surface.	Totals.	Accidents per 1,000,000 Tons of Mineral raised.	Persons employed Aboveground and Belowground.	Tons of Mineral raised.
1.—1851-1855.									
Average per annum	92·8	350·4	204·8	88·2	44·6	780·8	13·41*	229,468	58,222,894*
Ratio per 1,000 Persons employed Aboveground and Belowground ...	0·40	1·53	0·89	0·39	0·19	3·40	...	...	...
2.—1860-1864.									
Average per annum	59·2	394·4	139·6	120·4	56·8	770·4	8·89*	291,172	86,627,076*
Ratio per 1,000 Persons employed Aboveground and Belowground ...	0·20	1·35	0·48	0·41	0·20	2·64	...	...	...
3.—1870-1874.									
Average per annum	51·6	430·0	134·0	185·0	83·0	883·6	6·93	438,568	127,492,781
Ratio per 1,000 Persons employed Aboveground and Belowground ...	0·12	0·98	0·30	0·42	0·19	2·01	...	...	...
4.—1880-1884.									
Average per annum	29·8	455·6	87·6	198·8	92·0	863·8	5·04	503,941	170,079,381
Ratio per 1,000 Persons employed Aboveground and Belowground ...	0·06	0·90	0·17	0·40	0·18	1·71	...	...	..
5.—1890-1894.									
Average per annum	18·8	427·8	83·8	210·4	119·2	860·0	4·48	674,450	191,789,652
Ratio per 1,000 Persons employed Aboveground and Belowground ...	0·03	0·63	0·12	0·31	0·18	1·27	...	...	...
6.—1895-1899.									
Average per annum	18·4	425·8	62·0	235·4	114·6	856·2	3·98	704,816	214,773,656
Ratio per 1,000 Persons employed Aboveground and Belowground ...	0·02	0·61	0·09	0·33	0·16	1·21	...	...	...
7.—1899-1903.									
Average per annum	20·6	469·6	68·8	259·2	129·0	947·2	3·99	796,530	237,182,973
Ratio per 1,000 Persons employed Aboveground and Belowground ...	0·026	0·589	0·086	0·325	0·162	1·189	...	..	...

* Coal alone.

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TABLE II.—NUMBER OF DEATHS FROM DIFFERENT CAUSES OF ACCIDENTS IN AND ABOUT THE MINES OF GREAT BRITAIN AND IRELAND, UNDER THE COAL-MINES REGULATION ACTS.

PERIODS.	Explosions of Fire-damp and Coal-dust.	Falls of Roof and Side.	Shafts.	Miscellaneous Belowground.	On Surface.	Totals.	Deaths per 1,000,000 Tons of Mineral raised.	Persons employed Aboveground and Belowground.	Tons of Mineral raised
1.—1851-1855.									
Average per annum	231·0	368·4	236·6	101·8	47·6	985·4	16·92*	229,468	58,222,894*
Ratio per 1,000 Persons employed Aboveground and Belowground ...	1·00	1·61	1·03	0·44	0·21	4·29	...	...	...
2.—1860-1864.									
Average per annum	185·8	407·8	163·0	175·2	60·2	992·0	11·45*	291,172	86,627,076*
Ratio per 1,000 Persons employed Aboveground and Belowground ...	0·64	1·40	0·56	0·60	0·20	3·40	...	...	..
3.—1870-1874.									
Average per annum	174·8	441·2	146·4	202·8	85·0	1,050·2	8·23	438,568	127,492,781
Ratio per 1,000 Persons employed Aboveground and Belowground ...	0·40	1·01	0·33	0·46	0·19	2·39	...	...	...
4.—1880-1884.									
Average per annum	212·8	466·2	100·4	207·0	92·4	1,078·8	6·30	503,941	171,079,381
Ratio per 1,000 Persons employed Aboveground and Belowground	0·42	0·93	0·20	0·41	0·18	2·14	...	..	...
5.—1890-1894.									
Average per annum	188·2	440·2	95·6	235·6	120·4	1,080·0	5·63	674,450	191,789,652
Ratio per 1,000 Persons employed Aboveground and Belowground .	0·28	0·65	0·14	0·35	0·18	1·60	...	...	...
6.—1895-1899.									
Average per annum	65·6	439·6	71·0	271·4	116·6	964·2	4·48	704,816	214,773,656
Ratio per 1,000 Persons employed Aboveground and Belowground ...	0·09	0·62	0·11	0·38	0·16	1·36	...	...	...
7.—1899-1903.									
Average per annum	60·2	486·2	78·2	270·2	130·2	1,025·0	4·32	796,530	237,182,973
Ratio per 1,000 Persons employed Aboveground and Belowground ...	0·075	0·608	0·098	0·339	0·163	1·286	...	...	...

* Coal alone.

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time. This improvement ought to be fully recognized. It should be encouraging to owners, managers and workers. It may be said that the work of the mining engineer is to produce coal at the lowest cost to life and limb, with reasonable capital expenditure; by facilitating the work of the hewer and the transport from the working-face, to enable the workers to earn good wages with profit to the employer.

Tables I. and II. show the number of persons employed, mineral raised, accidents and deaths for periods of 5 years from 1851. It is not my intention to weary you with details of these; they are for your consideration, to enable you to draw your own conclusions. It may briefly be remarked that, from 1851 to 1855, the average annual number of persons employed throughout the United Kingdom was 229,468; from 1860 to 1864, it was 291,172; and from 1899 to 1903, the average number was 796,530. The annual output of mineral from 1851 to 1855 was 58,222,894 tons; from 1860 to 1864 it was 86,627,076 tons; and from 1899 to 1903 it was 237,182,973 tons. The death-rate per thousand persons employed from 1851 to 1855 was 4·29; from 1860 to 1864, 3·40; and from 1899 to 1903 it was 1·286.

TABLE III.—NUMBER OF DEATHS FROM DIFFERENT CAUSES OF ACCIDENTS IN THE LANCASHIRE AND CHESHIRE COAL-FIELD.

1899-1903.	Average per Annum.	Ratio per 1,000 Persons employed Aboveground and Belowground.
Explosions of Fire-damp and Coal-dust	5·8	0·064
Falls of Roof and Side	62·6	0·691
Shafts	7·8	0·086
Miscellaneous Belowground	28·8	0·317
Surface	11·8	0·130
Totals	116·8	1·289
Deaths per 1,000,000 Tons of Mineral raised ...	4·64	—
Persons employed Aboveground and Belowground	90,584	—
Tons of Mineral raised	25,181,133	—

The most striking feature in these tables is the large reduction in the loss of life from explosions: the death-rate from 1851 to 1855 was 1 per 1,000; and from 1899 to 1903 it was 0·075. The next feature is the reduction in shaft accidents: from 1851 to 1855 the death-rate was 1·03; and from 1899 to 1903 it was 0·098.

The Lancashire and Cheshire coal-field compares favourably

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with the United Kingdom in all other than the deaths from falls of roof and side. It can only be by continued, sustained effort that the much to be desired reduction under this head will be brought about.

It is my concluding observation to express the desire that you give your aid in endeavouring to reduce the great loss of life from falls of roof and side.

Col. GEORGE H. HOLLINGWORTH said that the best thanks of the Society were due to Mr. Gerrard for his excellent and instructive address, one of the best to which he had listened; and he had great pleasure in moving a hearty vote of thanks to him for it.

Mr. JOHN ASHWORTH seconded the proposal, which was carried by acclamation.

Prof. W. BOYD DAWKINS read the following paper on "A Section of the Glacial Deposits met with in the Construction of the New Docks at Salford": —

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A SECTION OF THE GLACIAL DEPOSITS MET WITH IN THE CONSTRUCTION OF THE NEW DOCKS AT SALFORD.

By Prof. W. BOYD DAWKINS, D.Sc., F.R.S.

The new docks now under construction at Salford, for the Manchester Ship Canal Company, are excavated in the Glacial deposits filling the ancient valley of the Mersey. These are remarkable for their irregularity, and, in the section exposed at the time of the writer's visit in the autumn of 1903, showed the lenticular arrangement of the clays, sands and gravels of which they were formed. They varied within the distance of a few feet. They contained the usual sea-worn pebbles and foreign and local stones, both angular and rounded, and more or less marked or smoothed by the action of ice. Among the foreign blocks, the andesite-tuffs of the Lake country, and more particularly of Thirlmere, may be noted. Among those of local derivation, a large block of Coal-measure sandstone was struck near the north-eastern corner of No. 9 dock, and in the line of the dock-wall. The writer is indebted to Mr. W. H. Hunter for the accompanying section, which he has kindly prepared for this paper (Fig. 1).

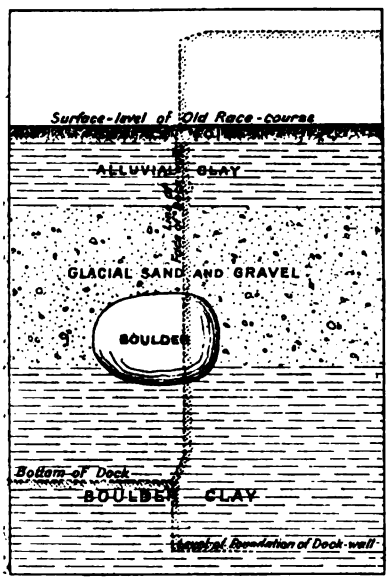

Fig. 1.—Section shewing the Position of the Large Boulder. Scale, 16 Feet to 1 Inch.

The block, so far as the writer's experience goes, is by far the largest as yet found in Lancashire in the Glacial drift. It

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is an irregular rounded mass of Coal-measure sandstone, reddish-grey, false-bedded, ripple-marked, and with the usual spangles of mica. It weighed about 45 tons, or nearly twice as much as the block of 25 tons of andesite-tuff found in Oxford Road, Manchester, and now in the quadrangle at Owens College. It measured 10 feet 6 inches in length, 7 feet 6 inches in depth and 6 feet 6 inches in breadth, and was embedded in the lower part of the Glacial gravels and rested on the Boulder-clay below. Part of it, as may be seen in the section, was left *in situ* behind the dock-wall; the rest was broken up and carried away.

The section is as follows:—

No.	Description of Strata.	Thickness of Strata. Ft.	In.
1	Surface soil	1	8
2	Alluvial clay	5	3
3	Glacial sand and gravel	13	6
4	Boulder-clay	20	0

The boulder rested at the junction of Nos. 3 and 4 beds. It was probably derived from some district in Lancashire, between Salford and the Lake-country.

Mr. Joseph Dickinson said that he had much pleasure in moving a vote of thanks to Prof. Boyd Dawkins for the interesting description that he had given of the boulder; he mentioned the scratchings upon it and the work of the Glacial ice, but the members might not be all agreed as to how those scratchings came. They had been produced by friction in some way, but he (Mr. Dickinson) always considered that the "ice story was very high," although he bowed to the Professor's superior knowledge.

Mr. William Watts, in seconding the vote of thanks, said that he wished that they could have a more definite idea of what a boulder was. He looked upon the local sandstone-grit blocks not as boulders, and preferred to keep the name of boulder for granite rock. This was a water-borne stone. For 7½ years he had been very extensively engaged in large excavations in the Little Don valley, on the other side of the Pennine chain, and he had been frequently struck with the large number of stones which immediately underlay the clay-bed of the valley, nearly every one of them being rounded or sub-angular and

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covered with $\frac{1}{32}$ inch of silica. It would be interesting to know how all these stones, both angular and sub-angular, became covered with silica. They might have been floated there by ice or water in motion, but there did not appear to be any clear evidence that ice-action had taken place in the Little Don valley—at all events, there were no traces of foreign boulders, erratic blocks or Boulder-clay. Possibly, at one time, a lake existed there, and the barrier which formed that lake would probably be in the gorge between Deepcar and Sheffield.

The resolution was adopted.

Prof. W. Boyd Dawkins, in acknowledging the vote of thanks, said that he had long observed in the valley of the Little Don, in the valley of the Derwent, and in some other valleys in that neighbourhood, on the east of the Pennine chain, that there was no drift with foreign stones such as occurred at similar levels on the western side. In the valleys where the Huddersfield reservoirs had been constructed, there was not enough clay for the puddle-trenches, and it was obtained from the Boulder-clay of Lancashire. This was due to the fact that the Pennine chain formed a barrier against the icebergs finding a way from the north-west to the south-east. It appeared that the ice could not pass over the higher ridges, but farther north, where the ridges were lower, the ice passed over in great force; and farther south, in the valley of the Trent and in the lower part of the valley of the Derwent, there were great sheets of Boulder-drift. At the place to which Mr. Watts referred there was no drift. He was not in a position to say what was going on in those localities, in the Glacial period: there might have been lakes, but there was certainly now no evidence of the existence of icebergs in those valleys, such as were found elsewhere and brought down great accumulations of Glacial sand and Boulder-clay and stone from the Lake-country and from the Scotch Highlands. These accumulations were found from Macclesfield, extending northward to the Lake-country and on to the margin of the Scotch Highlands.

Prof. W. Boyd Dawkins read the following paper on "The Permian and Carboniferous Rocks in a Section in High Street, Chorlton-on-Medlock, Manchester":—

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THE PERMIAN AND CARBONIFEROUS ROCKS IN A SECTION IN HIGH STREET, CHORLTON-ON-MEDLOCK, MANCHESTER.

By Prof. W. BOYD DAWKINS, D.Sc., F.R.S.

The section accompanying this paper (Table I.) and, by the courtesy of the Manchester Corporation, prepared by Mr. T. de Courcy Meade, the city-surveyor, relates to a boring at the Victoria Baths in High Street, completed in 1902. It is of great interest, because it shows the necessity of a revision of the Geological Survey map of the area of Manchester, made by Prof. Edward Hull as far back as 1862. It is also valuable, because it proves the presence of large quantities of water in strata which had hitherto been supposed to have little or none.

The Drift, 41 feet thick, in this section is part of the irregular mantle covering the rocks of the area of Manchester, and demands no special notice.

The red sandstone, 11 feet thick, is, in the writer's opinion, of Permian age, and a continuation westward under the Drift of those mapped as Permian at Ardwick and traversed in several borings and well-sections in that district.

The red and blue marly shales, with limestones and sandstones below, and penetrated in the boring to a depth of 708½ feet, are Upper Coal-measures of the Ardwick series. The two thin beds of limestone in the upper part of the section contain *Spirorbis* and present the usual compact structure and grey-red coloration of the *Spirorbis*-limestone. From the fact that the limestones here are two, instead of four in number as at Ardwick, it may be inferred that the section begins near the bottom of the Ardwick Limestones, and this is confirmed by the absence of the bed of hæmatite and of the thin coals characteristic of the upper beds at Ardwick. It is obvious, therefore, that, in High Street, the Upper coal-seams now being worked in the Manchester coalfield are within an easy workable distance from the surface, instead of being, as shown on the Geological Survey map,

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buried under a considerable thickness of Permians and of the Triassic pebble-beds. The distance from the surface to the first workable coal-seam (the Openshaw seam, 2 feet thick) is about 800 feet.

TABLE I.—SECTION OF STRATA IN A BORE-HOLE AT THE VICTORIA BATHS, HIGH STREET, CHORLTON-ON-MEDLOCK, MANCHESTER.

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
1	Soil	1	0	1	0
2	Red and blue boulder-clay	35	0	36	0
3	Gravel	5	0	41	0
4	Red sandstone-rock	9	0	50	0
5	Sandstone	2	0	52	0
6	Marl	13	0	65	0
7	Blue marl	17	0	82	0
8	Dark-blue shale	8	0	90	0
9	Blue marl	4	0	94	0
10	Ardwick Limestone	11	6	105	6
11	Mottled marl	6	6	112	0
12	Red and blue marl	8	0	120	0
13	Calcareous shale	5	0	125	0
14	Blue marl	4	0	129	0
15	Mottled marl	2	0	131	0
16	Ardwick Limestone	2	0	133	0
17	Calcareous shale	5	0	138	0
18	Mottled marl	6	0	144	0
19	Blue shale	19	0	163	0
20	Blue sandy shale	16	0	179	0
21	Dark-blue shale	11	0	190	0
22	Blue sandy shale	15	0	205	0
23	Shale	6	0	211	0
24	Variegated shale	15	0	226	0
25	Grey rock	2	0	228	0
26	Sandy shale	1	0	229	0
27	Mottled marl	6	0	235	0
28	Sandy shale	2	0	237	0
29	Grey rock	13	0	250	0
30	Sandy shale	6	0	256	0
31	Grey rock	4	0	260	0
32	Blue shale	3	0	263	0
33	Dark shale	3	0	266	0
34	Grey shale	16	6	282	6
35	Rock	1	6	284	0
36	Sandy marl	7	0	291	0
37	Grey rock	5	0	296	0
38	Variegated shale	1	0	297	0
39	Rock	8	0	305	0
40	Variegated shale	6	0	311	0
41	Grey bind	6	0	317	0
42	Grey rock	11	0	328	0
43	Sandy shale	2	0	330	0
44	Dark shale	11	0	341	0
45	Shale	6	0	347	0
46	Grey rock	3	0	350	0
47	Sandy shale	12	0	362	0
48	Grey rock	3	0	365	0
49	Sandy shale	12	0	377	0
50	Grey rock	10	0	387	0
51	Light shale	2	0	389	0
52	Variegated marl	10	0	399	0
53	Light shale	11	0	410	0
54	Grey shale	4	0	414	0
55	Dark shale	5	0	419	0
56	Sandy shale	10	0	429	0
57	Variegated shale	4	0	433	0
58	Grey shale	3	0	436	0
59	Sandy shale	9	0	445	0
60	Grey sandstone	3	0	448	0
61	Sandy shale	5	0	453	0
62	Dark shale	8	0	461	0
63	Brown shale	8	0	469	0
64	Variegated marl	17	0	486	0
65	Red marl	8	0	494	0
66	Variegated marl	18	0	512	0
67	Brown marl	23	0	535	0
68	Variegated marl	5	0	540	0
69	Blue shale	4	0	544	0
70	Variegated marl	6	0	550	0
71	Red marl	4	0	554	0
72	Variegated marl	10	0	564	0
73	Brown marl	4	0	568	0
74	Variegated marl	5	0	573	0
75	Marly and sandy shale-beds	2	0	575	0
76	Variegated marl	13	0	588	0
77	Red marl	14	0	602	0
78	Variegated marl	4	0	606	0
79	Red marl	26	6	632	6
80	Variegated marl	25	0	657	6
81	Red and blue bind	12	0	669	6
82	Variegated marl	4	0	673	6
83	Red marl	7	0	680	6
84	Variegated marl	9	6	690	0
85	Hard marl: variegated	4	0	694	0
86	Brown sandstone	11	6	705	6
87	Marl with sandstone-beds	4	0	709	6
88	Blue bind	4	0	713	6
89	Brown sandstone	4	0	717	6
90	Hard brown sandstone	9	6	727	0
91	Variegated marl	7	0	734	0
92	Sandy shale	20	0	754	0
93	Light blue sandy shale	6	6	760	6

The boring at High Street is 3,564 feet to the west of the boundary shown on the Geological Survey map, as that between

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the Pebble-beds and the Permian strata. It does not, however, follow that the Permians occupy the whole of the intervening area. Their general dip in this area is to the west, and if that had been maintained here, instead of being thin, they would have presented a thickness exceeding 100 feet. They are, therefore, probably on the upthrow side of a fault running in a northerly direction parallel to the other main faults in the district, but on this point further evidence is needed.

The boring was made for the supply of the Victoria Baths. It was directed to the water known to exist in the pebble-beds and in the Permian sandstone of the district. There were no pebble-beds, and the Permians were too thin to yield an adequate quantity of water. When the boring had attained a depth of 205 feet from the surface, in the Ardwick Limestone series, the writer advised the Corporation to abandon it, on the ground that as a rule there was little or no water in these rocks and that it was usually of bad quality. They, however, carried it down to a depth of 760½ feet, and have obtained a supply from the beds below the Ardwick Limestone of 8,000 gallons per hour, a supply, so far as the writer is aware, without precedent from a boring in these rocks. On these grounds alone, the writer thinks that the boring deserves to be put on record, as a contribution to our knowledge of the water available from borings in the Upper Coal-measures.

Mr. S. S. PLATT, in moving a vote of thanks to Prof. W. Boyd Dawkins for his paper, said that one day he received an invitation from Mr. T. de Courcy Meade to visit the site of the boring in High Street, and on seeing the material that had been taken out he pronounced it as belonging to the Upper Coal-measures, and said he was afraid that the Corporation would find very little water below that depth. He was, however, glad to learn that Mr. Meade went on with his boring, and that a large supply of water had been found.

Mr. JAMES ATHERTON seconded the proposal, which was adopted.

Mr. JOSEPH DICKINSON said that, some years ago, he saw a letter in the newspapers from someone who described the finding of the Ardwick Limestone in the neighbourhood of

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Withington, and the members knew that the cutting for the sewers at Levenshulme went through those beds, so that the upthrow of the Upper Coal-measures in that part of the district has been to some extent proved, since Dr. Hull filled in the map for the Geological Survey, without the information which is now known. There were intercepting faults, and that map took no cognizance whatever of them, and it would be well if Prof. Boyd Dawkins would gather together the facts that were known and lay them down for the revision of that map in the future. It was a pity, at this date, that information which was now superseded should still be published. There were many other errors: the carrying of the great fault from Manchester to Stockport was a thing that he could never look upon as correct, and the finding of Permian rocks at Radcliffe Bridge and Heaton Park were unnoticed on the map.

The President (Mr. John Gerrard) said that all would be agreed that these maps should be revised. It was of great importance, in connection with the extension of the coal-field, and especially in the neighbourhood of Manchester, that accurate geological information should be available. Prof. Boyd Dawkins and Mr. Dickinson had referred to the Heaton Park borings and to a very serious error in the Geological Survey map in association therewith. There were several wells in the neighbourhood of High Street, and the records of these wells might be of service to geologists, by affording information as to the position of faults and the continuation of the Coal-measures.

Prof. W. Boyd Dawkins, replying to the discussion, said that he had many records of borings in Manchester, and Mr. Charles Chapman had many more. He hoped to mark their positions on the 6 inches Ordnance Map, for future use in the revision of the old map of the Geological Survey.

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MANCHESTER GEOLOGICAL AND MINING SOCIETY.

ORDINARY MEETING,
HELD IN THE ROOMS OF THE SOCIETY, 5, JOHN DALTON STREET, MANCHESTER,
DECEMBER 13TH, 1904.

MR. JOHN GERRARD, PRESIDENT, IN THE CHAIR.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. STEPHEN EVERARD BASTOW, Hazlehurst, Whitefield, Manchester.
Mr. JOSEPH CARTER, Rainford Colliery, St. Helens, Lancashire.
Mr. JOSEPH CASS, Peasley Cross Colliery, St. Helens, Lancashire.
Mr. R. E. KNOWLES, Taylor Green Colliery, Springvale, Darwen.

ASSOCIATE MEMBER—

Mr. GEORGE BLACKWELL, The Albany, Liverpool.

Mr. JOHN J. WHITEHEAD's "Notes on Coal in the Transvaal" were read as follow:—

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NOTES ON COAL IN THE TRANSVAAL.

By J. J. WHITEHEAD.

Geology.—Carboniferous deposits of varied extent, quality and thickness are found in many parts of South Africa, but owing to the paucity of fossils, the precise geological age of these deposits has not been determined: they are, however, generally believed to be subaqueous and lacustrine. The only fossil brought to the writer's notice was *Glossopteris*, found near Brugspruit; *Calamites* and *Sigillaria* have also been found

TABLE I.—COAL-OUTPUT OF THE TRANSVAAL IN 1903.

District and Name of Company.	Coal Mined. Tons	Value. £
Boksburg:		
Apex Mines, Limited	181,433	68,037
Brakpan	249,617	89,516
Cassel Coal Company, Limited: Springs ...	87,323	33,226
Clydesdale (Transvaal) Collieries, Limited	218,430	94,843
Great Eastern Collieries, Limited	159,861	60,398
Springs	102,350	40,248
Tyne Valley Colliery, Limited	92,712	37,530
Victoria East Collieries, Limited	1,649	577
Heidelberg:		
New Fortuna Company, Limited	4,962	1,489
Nigel Gold-mining Company, Limited ...	12,840	3,677
South Rand Exploration Company, Limited	2,291	1,145
Middelburg:		
Cardiff	1,902	707
Cassel Coal Company, Limited: Landau ...	41,623	17,481
Coronation Colliery Company, Limited ...	20,031	7,953
Douglas Colliery, Limited	71,919	24,044
Natal Ocean Coal Company, Limited ...	656	262
Rogerston Collieries, Limited: Crown ...	63,488	23,771
Transvaal and Delagoa Bay Collieries, Limited	378,281	138,728
Transvaal Consolidated Coal-mines, Limited	33,372	13,468
United African Lands, Limited	363	182
Witbank Colliery, Limited	325,319	127,226
Zwartzkopjes	88	30
Vereeniging:		
Vereeniging Estates, Limited	207,674	99,772
Other Districts:		
Carolina	100	75
Totals	2,258,284	884,385

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near Middelburg. Pending further development, research, and expert geological opinion, the question of the exact age of the beds, whether Triassic or Carboniferous, yet remains to be determined.

Production.—The Transvaal, the greatest coal-producer of the five South African colonies, may be divided into four districts, so far as production is concerned (isolated areas where sinking, trial or otherwise, is being carried on, being excluded). The output for 1903 of the various collieries in these districts is given in Table I.

The output for the past five years is given in Table II.

TABLE II.—COAL-OUTPUT OF THE TRANSVAAL FROM 1898.

		Coal Mined. Tons.	Value. £	Value per ton. s.	d.
1898	...	1,907,808	668,346	7	0·47
1899	...	1,735,282	619,406	7	1·66
1900	...	506,074	197,127	7	9·48
1901	...	797,144	329,113	8	3·08
1902	...	1,590,333	637,640	8	0·22
1903	...	2,258,284	884,385	7	9·98

Boksburg District.—The Boksburg-Brakpan-Springs district, although having the largest output for 1903, produces, curiously enough, the most inferior coal of any. It extends from Boksburg eastward towards Springs, and is 16 miles long (Fig. 1, Plate XI.). Discovered in 1887, it was the only coal available when the Rand mines were opened up. Since then, however, coal of superior quality and cheaper to work has been discovered and opened up; especially that from Witbank, which, despite a high railway-rate, will, in the opinion of the writer, sooner or later drive out the East Rand coal from the market. Without the interest, direct or indirect, held by some of the gold-mining companies in the collieries of the East Rand, the output for 1903 would not have been so high; and, moreover, the number of collieries in the East Rand is decreasing, while those in the Middelburg district are increasing.

An average analysis of the coal in this district is as follows: Fixed carbon, 62 per cent.; volatile matter, 15·1 per cent.; moisture, 0·6 per cent.; sulphur, 0·3 per cent.; and ash, 22 per cent. One pound of the coal will evaporate 10·6 pounds of water.

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The coal-seams in this district have a total thickness of about 80 feet. The coal is dull, of splinty appearance, weathers badly, and is very liable to spontaneous combustion. It is, moreover, costly to mine, and requires careful screening.

From a colliery manager's point of view, this district is perhaps the least interesting of any, although of special interest as regards the easterly extension of the gold reefs. The coal-measures of the East Rand lie upon the Witwatersrand formation.

In 1902, a bore-hole was put down by the Apex Mines, Limited, to a depth of 1,000 feet, and since continued to a total depth of 2.542 feet 9 inches, the Main Reef quartzitic shale being intersected at the depth of 1,576 feet. The Main Reef Leaders were intersected as follows:—At 1,468 feet 7 inches, 5 inches; 1,486 feet 6 inches, 3 inches; 1,487 feet 10 inches, 4 inches; and 1,492 feet 3 inches, 2 inches. The highest gold-value averaged 10 dwts. over the thickness of 4 inches. There was no Main Reef, but a series of white quartz-veins in a greenish quartzitic body, carrying no gold-value. The occurrence of the Main Reef contact at this depth was held to confirm the assumption of an upthrow fault; and the bore-hole was continued to the depth of 2,542 feet 9 inches, in order to complete the correlation with the underlying quartzites. The contact-schist was proved to be 614 feet thick, and the underlying quartzite contained diabase-intercalations of considerable thickness.

This information being incomplete, another bore-hole was put down on the north-eastern side of the property, to a depth of 2,873 feet. The Main Reef contact was intersected at 2,833 feet 6 inches. It is estimated that this, under ordinary conditions, should vary from 9 dwts. to 19 dwts., over a stoping width of 3 feet. These results are highly satisfactory, and form an asset of no mean order.

Further east, on the Welgedacht farm, three bore-holes have intersected the Main Reef at depths of 2,723 feet, 2,385 feet and 3,090 feet respectively. Farther eastward of this farm, boring is also being carried on, and, in all probability, the reef will be struck at an even greater depth.

Heidelberg District.—Coal-mining in the Heidelberg district is unimportant, although several isolated areas of coal are known

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to exist, and some have been worked to a small extent. The Nigel Gold-mining Company, Limited, mine their own coal. The South Rand Exploration Company, Limited, have sunk two pits, 600 feet deep, to a seam 40 feet thick: the lower 11 feet only of which is being worked. This coal is of excellent quality, and equal to if not superior to Witbank coal. The plant, when erected, will be the most modern in the Transvaal. A colliery branch-line, about 12 miles long, is being made to connect this colliery with the main line.

Middelburg District.—The best coal worked in the Transvaal, comes from the vicinity of Witbank in the Middelburg district. The coal-measures, around Witbank and Brugspruit, have been proved by bore-holes to a depth of 500 feet, shewing six seams of coal. Owing, however, to denudation on an extensive scale, these six seams are by no means generally found throughout the district, and only in two instances, so far as the writer is aware, are they present (Appendix and Fig. 3, Plate XII.).

The measures, for the most part, consist of grits, sandstones, micaceous and carbonaceous shales and sandstones, interstratified with seams of coal of various thicknesses. The shales and sandstones, in almost every instance, form an excellent roof. The plan (Fig. 2, Plate XII.) shews the positions of the various collieries and farms where coal has been discovered: the writer however, particularly wishes to point out that coal has been discovered on many farms not shewn on the plan, but owing to these farms being situated a considerable distance from the railway, or the coal itself being of inferior quality, their indication on the plan was not considered necessary.

The most valuable seam, and the one most generally found throughout the district, is the No. 5 seam; and this is of varying quality (so far as shale and partings are concerned) and thickness.

In some cases, the seams have been opened up by adits only, and as the strata lie practically horizontal, little is known of the strata above and below the seams. Correlation, therefore, of the seams is not altogether easy, especially in view of the number of outcrops due to the undulating surface of the ground and to extensive denudation. For topographical surveys, however, in relation to the coal-measures, it is usual to work from the No. 5 seam as a datum-horizon, as struck by the bore-hole on

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Blesboklaagte farm, north of Witbank station (Appendix No. 7 and Fig. 3, Plate XII.). The section in Witbank colliery is practically the same as that given by this bore-hole.

On the north side of the railway are situate three collieries, belonging to the Transvaal and Delagoa Bay Collieries, Limited, the Middelburg Steam Coal & Coke Company, Limited, and the Coronation Colliery Company, Limited, the two last-named being new. A section of the strata passed through in the Middelburg Steam Coal & Coke Company, Limited's No. 1 Pit is given in Appendix No. 1; and the same section may be taken as coincident with that passed through at the Coronation colliery; but the No. 5 seam at the latter colliery is inclined to be more shaly than at the Middelburg pit.

North of the railway-line, the country is somewhat flat, whereas to the south it is undulating. Sections are given in the appendix at Blauwkranz, Elandsfontein and Landau colliery (Klipfontein). In all probability, the No. 5 seam extends for some distance north and north-east of the Middelburg Steam Coal & Coke Company, Limited's holding.

Transvaal and Delagoa Bay Colliery.—This colliery is situated north-west of the railway-line on Driefontein farm, having an area of 4,450 acres, and working the No. 5 seam about 16 feet thick, from a pit 104 feet deep (Fig 3, Plate XII.). The coal is raised by a winding-engine with two cylinders, 13 inches in diameter by 2 feet stroke, geared 2½ to 1. The mine is worked by the pillar-and-stall system, with pillars 60 feet square, and stalls 22 feet wide. A branch-line, 3½ miles long, connects the colliery with the main line at Witbank station.

Middelburg Steam Coal & Coke Company, Limited.—Sinking operations for the present winding-shaft, No. 2 pit, commenced in April, 1903, and were concluded on May 23rd, at a depth of a little over 80 feet, when a seam 14½ feet thick was proved. Appendix No. 1 shews the strata passed through in the No. 1 pit (air-shaft, 7 feet by 5 feet) where the coal was 12½ feet thick. Here the measures are decidedly uniform, of a hard nature, affording splendid roof-protection to the seam, unlike many seams in the Transvaal, which lie near the surface with roofs of a broken nature, and are therefore much weathered and inferior in quality. The coal of this seam gives

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an analysis second to none in the Transvaal at the present time. The following analysis of the coal of the No. 5 seam was made by Mr. E. Riley, London:—I.: Carbon, 75·53 per cent.; hydrogen, 5·50 per cent.; oxygen, 8·92 per cent.; nitrogen, 1·96 per cent.; sulphur, 1·07 per cent.; and ash, 7·02 per cent. II.: Volatile matter, 31·25 per cent.; and coke, 68·75 per cent. The specific gravity is 1·34. One pound of coal contains 7,810 calories, and will evaporate 14·54 pounds of water.

The area of the property is about 1,500 acres. The colliery is situate 1½ miles from Witbank station, with which it is connected by a siding. The output will shortly amount to 1,500 tons a day, dealt with by screening-plant of modern and approved type. A Worthington duplex-pump (with a steam-cylinder, 6 inches in diameter, and a ram 4 inches in diameter by 6 inches stroke) running 18 hours per day, pumps all the water (1,000 gallons an hour) made in the mine.

Coronation Colliery.—The area held by this company exceeds 500 acres, adjoining the southern boundary of that held by the Middelburg Steam Coal & Coke Company, Limited. There is one shaft on the property sunk to the No. 5 seam, which, although slightly thicker than at the adjoining colliery, is not so clean: the shale and partings being thicker. This colliery has siding-connection with the railway.

Witbank Colliery.—The colliery covers an area of 8,920 acres, the whole of which, with the exception of 1,000 acres, is freehold. The No. 5 seam varies from 12 to 16 feet in thickness. It is worked by the pillar-and-stall system, the pillars being 20 feet square and the stalls 20 feet wide. The seam is practically horizontal, makes little water, no gas, and the roof and floor are both excellent. The output is 1,300 tons a day, raised by a direct-acting winding-engine, with a cylinder 16 inches in diameter by 3½ feet stroke. The coal is screened on two belts, 40 feet long for round coal, and two smaller belts for small coal.

Landau Colliery.—This colliery, owned by the Cassel Coal Company, Limited, of Springs, suffered much during the war, the underground workings, apart from extensive surface-damage, being flooded to within a few feet of the surface. Two

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seams are being worked, namely:—No. 1 seam, a smithy and gas coal; and No. 5 seam, a house and steam coal. The colliery is connected by a siding with Brugspruit station.

Methods of Working.—As a general rule, the stalls are driven 20 feet wide, and pillars are formed from 20 to 30 feet square. Little or no timber is required. The seams make little water, and fire-damp is practically unknown. It is usual in the No. 5 seam to work the bottom 6 feet, leaving the upper portion of the seam as a roof. The mine is divided into districts, so many boys (Kaffirs) being told off to each district under a white overseer; the boys do all the mining, holing, drilling, hewing, filling and tramming to the nearest shunt; but the blasting (by dynamite) is done by the white overseer. The main roads or levels are worked by endless-rope haulage; the capacity of the tubs is about 20 cubic feet. The boys are paid 2s. a day and their food (mealie-meal); they live in a compound on the mine, and are well housed, fed and cared for. There is a small hospital on every mine for the sick and injured; and on some, for the white workmen, a plunge-bath and a library.

Vereeniging Estates.—The coal-areas of these estates amount to 97,000 acres. There are two collieries working:—The Central mine, north of the Vaal river in the Transvaal, and the Cornelia mine, south of the Vaal river in the Orange River Colony. Seams, 10 to 20 feet thick, are being worked at the Cornelia mine, and 10 to 16 feet thick at the Central mine. The former mine is well equipped, having a wrought-iron headgear. Doubtless the line, in relief of the present main line, from Vereeniging to Johannesburg, will prove of especial benefit to these collieries, as providing a shorter and easier route, in point of gradient, to the West Rand gold-mines (Fig. 1, Plate XI.).

Other Districts.—An excellent seam of coal, probably the No. 5 seam of the Witbank district, crops out on Kromdraai farm, north of Wakefield station on the Pretoria-Middelburg railway. The thickness at the face of an adit, 120 feet long, is 19 feet: the top coal, 8 feet thick, resembling, in the writer's opinion, the bone coal of Lancashire, has been found to be an excellent smithy coal, and the lower coal, 11 feet thick, is a

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steam and house coal. About ¾ mile east of the adit, two rectangular prospecting shafts, 240 feet apart, have been sunk to this seam, 45 and 63 feet deep respectively. Analyses of the coal have been made as follows:—I.: Shaft, fixed carbon, 56·26 per cent.; volatile matter, 34·67 per cent.; ash, 8·74 per cent.; sulphur, 0·01 per cent.; and moisture, 0·32 per cent. II.: Adit, fixed carbon, 61·25 per cent.; volatile matter, 27·83 per cent.; ash, 9·75 per cent.; sulphur, 0·02 per cent.; and moisture, 1·15 per cent. The yield of coke of the coal from the shaft was 64 per cent.; and from the adit 71·02 per cent. The evaporative efficiency averaged 12·1 pounds and 12·6 pounds of water respectively. The area of available coal is about 2,000 acres, but the distance from the railway (5 miles) appears to have prevented this seam from being worked—and since the approximate cost of a colliery-siding in this colony is £4,000 a mile, it often forms an important item in the capital-account, apart from the delay involved in its construction.

Douglas colliery, lying farther southwestward, on Goedvertrouw farm, is working an excellent seam of coal 12 feet thick by an adit; and possibly this seam is the same seam as that proved on the Kromdraai farm.

Coal also exists north of the railway-line at Bronkhorstspruit, but of quality too inferior to merit more than passing mention.

About 19 miles southwest of Johannesburg, on the Vereeniging to Johannesburg new railway, are three farms of interest from a geological point of view. In this case, the coal, locally known as "drift coal," lies in the dolomite hollows, or in large basins of dolomite, formed partly by the upheaval of the older rocks and partly by atmospheric and aqueous influences; and into these basins or hollows the vegetable matter, now forming the seams, is supposed at some period to have been washed or drifted.

Much discussion has taken place as to the mode of formation and the derivation of this carbonaceous matter. Mr. J. A. Logan, the late manager of the Cyferfontein colliery, referring to the basin extending from Cyferfontein into Zuurbekom farm, stated that within a certain area, the carbonaceous matter came from a southwesterly direction; a conclusion based upon the facts that (*a*) the specific gravity of the vegetable

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matter, being less than that of the later drift, such as mud, sand, etc., the carbonaceous matter would be carried to the farther ends of the basins; and (*b*) the best coal is found at the north-eastern end, and the inferior coal at the south-western end, of the basin.

Having had an opportunity of discussing this theory with Mr. Logan and of going over the ground, the writer is inclined to agree with him, so far as the dull coal is concerned; but not in regard to the bright coal, which is found interlaminated with the dull coal. In the Transvaal, the dull coal contains less volatile matter than the bright, and is generally found overlying the latter. Moreover, the writer is inclined to the theory that the bright coal was deposited *in situ*; that the dull coal was washed or drifted in at a later period, and that, while in course of transit, it was deprived of a certain amount of its volatile matter. In the No. 5 seam, at Witbank collieries, the bright coal contains in places thin streaks of dull coal; and the writer suggests that these streaks were caused by heavy tropical rains or floods. Divers opinions exist in the Transvaal as to the origin of the dull and the bright coal, much time has been spent in discussion, and new theories, from home, would prove welcome and refreshing.

The average of three analyses of the coal proved on the Cyferfontein farm is as follows:—Fixed carbon, 49·16 per cent.; volatile matter, 43·01 per cent.; and ash, 7·83 per cent.

On Zuurbekom farm, another similar coal-basin exists, unproven, about 1,100 acres in extent; and yet another of about 1,700 acres, also unproven, on the Klipriviersoog farm (Fig. 1, Plate XI.).

The shaft on the Cyferfontein farm was sunk to a depth of 530 feet, when the dolomite was struck: 200 feet of carbonaceous matter was passed through, 70 feet of which was considered good marketable fuel. This colliery commenced winding coal shortly before the war, and it has not been restarted since the conclusion of peace.

Several isolated areas of coal exist to the south and west of Heidelberg, and in certain cases they have been worked to a small extent.

At Onverwacht, northwest of Bethel, two seams of coal,

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15 and 7 feet thick respectively, have been proved under an area of about 2,300 acres. These measures are supposed to rest upon the Witwatersrand formation. So far, this is mere conjecture, for in no instance on this farm can the underlying formation be seen.

Coal of good quality has been found at Bethel and Ermelo. An average analysis of coal from the Bethel district is as follows: Fixed carbon, 53·15 per cent.; volatile matter, 40·27 per cent.; sulphur, 0·08 per cent.; ash, 6·05 per cent.; and moisture, 0·45 per cent. The evaporative power is 12·4 pounds of water; and the coal yields 58·73 of coke. Until the Springs and Ermelo railway, now in course of construction, has been completed, mining in this neighbourhood, to any practical extent, may be considered impossible.

On the Witrand farm, south of Carolina, and 3 miles from the proposed railway from Carolina to Ermelo, seams 4 feet and 6 feet thick respectively have been proved by an adit and prospecting shaft. Nearer to Carolina, on the Droogvallei farm, another seam, varying in thickness from 2 feet 2 inches to 3 feet 2 inches, has been proved by three adits. An analysis yielded the following results:—Fixed carbon, 58 per cent.; volatile matter, 30·9 per cent.; sulphur 1·5 per cent.; and ash, 9·6 per cent. The evaporative power is 12 pounds of water.

As the cuttings, embankments and culverts are all constructed from Machadodorp to Carolina, the final completion of this section of the railway from Machadodorp to Ermelo may be expected in the near future.

On the Paardeplaats farm, adjoining the railway-line at Belfast, the Belfast colliery, owned by the Transvaal Consolidated Coal-mines, Limited, is working a seam of coal from 16 to 20 feet thick, under about 400 acres. The coal is shaly and high in ash. Operations in a small way have also been started by this company on the Honingkranz farm, near Balmoral. Coal also exists on Blyvooruitzigt, south of Belfast, and on the Elandskloof, Haartebeestefontein, Lakenvlei and Swartzkopjes farms, north of Belfast.

On the Swartzkopjes farm, a seam 18 feet thick has been worked to a small extent, the coal being carted to Belfast by ox-waggon. This seam in the north-eastern corner of the farm, lies under a slight depression, under only 4 feet of soil and clay,

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and the coal has been wrought by open work or quarrying. An analysis of the coal is as follows:—Fixed carbon, 68·59 per cent.; volatile matter, 18·17 per cent.; sulphur, 0·54 per cent.; ash, 9·26 per cent.; and moisture, 3·44 per cent. Owing to the high percentage of moisture, which is perhaps only to be expected from a surface-coal lying in a basin or depression, the evaporative power is as low as 9·71 pounds of water.

Within the triangle, Middelburg, Belfast and Roos Senekal, vast deposits of iron-ore are known to exist. When the railway is running from Belfast to Lydenburg, there may be some possibility of the coal being worked north of Belfast. There can be no doubt that the country in the vicinity of Middelburg will, in the future, become the "black country" of the Transvaal.

Between Witbank and Middelburg, the No. 5 seam is denuded on each bank of the Olifants river, but traces of the outcrops can be seen on either bank a short distance from the river. Sinking operations have recently been concluded on the Vaalbank farm proving a good seam of coal.

Summary.—Owing to the extremely shallow depth at which coal is worked in the Transvaal, brick-lining of shafts is unknown. The shafts are generally rectangular, and lined, principally with pitchpine, where considered necessary; in passing through hard rock or sandstone, the shaft-walls are left bare. Where only one shaft is sunk on a property (and the law does not compel the sinking of two shafts), it is divided into four compartments:—Ladder-way, two winding compartments, and one pumping compartment. The existence of this primitive method is to be deprecated, for reasons too well known to need enumeration; it may be added, however, that collieries managed by men trained and qualified in Great Britain generally have two shafts.

The measures are generally free from faults and dislocations, such as are generally met with in England; they are, however, subject to intrusions of igneous dykes (whinstone and dolerite) sometimes 1,000 to 1,500 feet wide, but not perhaps to the same extent as the seams in Natal. The igneous dykes have no perceptible effect upon the general lie of the seams, but the quality of the coal changes within a certain radius,

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according to the size of the dyke, the entire character of the seam being altered and becoming more anthracitic by the expulsion of a percentage of the volatile matter. The action of the heat, once contained in the dykes, can be discerned in the seams, and in the roof and floor as well. The collieries around Witbank are particularly free from igneous intrusions, so far as development up to date has shown; but in districts and areas where the measures rest more directly upon the older formations, this is not the case. These igneous dykes, in the majority of instances, intersect the seams at right angles, often, in the case of several seams overlying one another, passing through seam after seam in a vertical line, till they reach the surface, where they appear to form a cap, like an inverted saucer, and to have overflowed. It is practically certain that the intrusion took place after the formation of the seams of coal.

Ventilation is chiefly supplied by fans, and at times it is by no means easy to maintain: for, owing to the warm climate, the high altitude, and the dryness of the air, the temperature of the intake air is sometimes several degrees above that of the mine itself.

In the Transvaal, candles chiefly are used: a few safety-lamps being kept for use in cases of emergency.

Little or no timber is required, which is fortunate, as the cost of mining timber delivered at Witbank station is:—Pitch-pine, 4s. 6d. per cubic foot; and Oregon pine, 3s. 10½d. per cubic foot.

The coal, except that used by the railway-companies and gold-mines, is generally filled into bags holding 200 pounds, and 10 bags equal a ton of 2,000 pounds. The general cost of coal in the Witbank district is 3s. 6d. to 4s. a ton; and the selling price is 7s. 6d. to 8s. a ton at the pit.

The following are the railway-rates per ton of 2,000 pounds, to the principal markets, from Witbank station:—Barberton, 13s. 3d.; Delagoa Bay, 10s. 4d.; Johannesburg, 9s. 5d.; Pietersburg, 14s. 9d.; Potchefstroom, 13s.; and Pretoria, 7s. 2d.

Coal is now selling on the Rand for steam-raising purposes at 16s. to 18s. a ton, and in comparing that from Witbank with Springs coal it is generally held that two bags of the former are equal to three of the latter.

Coke-making has not, perhaps, received its due share of

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attention. English coke is selling in Johannesburg at £8 a ton, and Transvaal coke at £3: the latter being far below the market-value of the former, owing to its persistent tendency to crumble when exposed to the heat of the blast-furnace. Recently, however, a few tons manufactured from the No. 5 seam, at Witbank, have given better results.

APPENDIX.

No. 1.—No. 1 Shaft of the Middelburg Steam Coal and Coke Company, Limited.

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
1	Soil	1	0	1	0
2	Gravel	6	0	7	0
3	Red clay	3	0	10	0
4	Sandstone and grit, soft	9	0	19	0
5	Sandstone and grit, very hard	22	0	41	0
6	Micaceous shale and sandstone	7	0	48	0
7	Carbonaceous shale ...	11	0	59	0
8	Micaceous shale and sandstone	8	6	67	6
9	Shale	1	6	69	0
	No. 5 Coal-seam—				
10	**COAL***	12	6	81	6
11	Coarse grit	0	6	82	0

* A coal-seam, 5 feet thick, has been proved below this seam.

No. 2.—No. 3 Bore-hole, at Blauwkranz Farm, near Brugspruit, for the Anglo-French (Transvaal) Navigation Coal Estates, Limited, 1897.

No	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
1	Sandy soil	20	0	20	0
2	Blue limestone (?) ...	35	0	55	0
3	Hard red sandstone ...	3	0	58	0
4	Blue limestone (?) ...	1	0	59	0
5	White sandstone ...	18	0	77	0
6	Hard grey sandstone	23	0	100	0
7	Sandstone and shale...	38	0	138	0
8	Hard shale	4	0	142	0
9	Shale	2	0	144	0
10	Grey sandstone ...	16	0	160	0
11	Sandstone and shale...	12	0	172	0
12	Hard fine sandstone...	18	0	190	0
13	Dark sandstone ...	12	0	202	0
14	Sandstone and shale...	3	0	205	0
	No. 1 Coal-seam—				
	Ft. In.				
15	**COAL** ... 1 3				
16	Shale ... 3 9				
17	**COAL** ... 5 6				
	——	10	6	215	6
18	Sandy shale	3	6	219	0
19	Shale	21	0	240	0
20	Coarse grey sandstone	7	0	247	0
21	Shale	0	6	247	6
22	Grey sandstone ...	3	6	251	0
	No. 2 Coal-seam—				
23	**COAL**	2	6	253	6
24	Hard grey sandstone	3	6	257	0
	No. 3 Coal-seam—				
25	**COAL** (no details given)	24	0	281	0
26	Dark sandstone ...	19	0	300	0
	No. 4 Coal-seam—				
27	**COAL**	0	6	300	6
28	Dark sandstone ...	3	0	303	6
29	Sandy shale	14	0	317	6
30	Shale	8	0	325	6
31	Sandy shale	15	0	340	6
	No. 5 Coal-seam—				
	Ft. In.				
32	**COAL** ... 10 0				
33	Shale ... 0 6				
34	Sandstone... 1 6				
35	**COAL** ... 8 0				
	——	20	0	360	6
36	Sandstone	13	6	374	0
	No. 6 Coal-seam—				
37	**COAL**	4	3	378	3
38	Conglomerate sandstone	34	3	412	6
39	Dark fine sandstone...	25	0	437	6
40	Hard shaly slate ...	25	0	462	6
41	Broken slate	5	0	467	6
42	Hard slate	6	0	473	6
43	Gritty slate	2	0	475	6
44	Slate	12	0	487	6

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No. 3.—No. 1 Pit, at Elandspontein Farm, near Brugspruit, for the Anglo-French (Transvaal) Navigation Coal Estates, Limited.

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
1	Red soil	5	0	5	0
2	Hard soil	4	0	9	0
3	Yellow clay	23	0	32	0
4	Coarse sandstone ...	2	0	34	0
5	Yellow clay	0	9	34	9
6	Red sandstone ...	0	6	35	3
7	Yellow clay	2	9	38	0
8	Yellow sandy clay ...	4	0	42	0
9	Black clay	2	6	44	6
10	Clay and shale ...	5	6	50	0
11	Dark shale	6	0	56	0
12	Red sandstone ...	1	0	57	0
13	Hard dark-grey shale	10	0	67	0
14	Dark sandstone ..	2	6	69	6
15	Grey sandstone ...	2	6	72	0
	No. 5 Coal-seam—				
		Ft.	In.		
16	**COAL** ...	1	6		
17	Dark shale ...	0	6		
18	**COAL**, shaly	1	5		
19	**COAL**, shaly	1	7		
20	**COAL**, shaly	1	0		
21	**COAL**, shaly	3	2		
22	**COAL** ...	12	10		
		——		22	0	94	0

No. 4. No. 2 Bore-hole, at Klipfontein Farm, near Brugspruit, for the Landau Transvaal Colliery Company.

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
1	Soil	4	6	4	6
2	Gravel...	1	0	5	6
3	Soft white sandstone	8	6	14	0
4	Soft brown sandstone	27	0	41	0
5	Sandstone and shale...	45	9	86	9
	No. 1 Coal-seam—				
6	**COAL**	7	0	93	9
7	Shale	5	11	99	8
8	Sandstone	0	4	100	0
9	Shale	0	6	100	6
10	Sandstone	4	0	104	6
11	Grey shale	4	0	108	6
12	Black shale	16	6	125	0
	No. 2 Coal-seam—				
13	**COAL**	0	6	125	6
14	Conglomerate grits ...	1	6	127	0
15	Sandstone	1	0	128	0
16	Shale	0	6	128	6
	No. 3 Coal-seam—				
		Ft.	In.		
17	**COAL** ...	0	6		
18	Shale ...	1	4		
19	**COAL** ...	0	8		
20	Shale ...	1	0		
21	**COAL** ...	1	2		
22	Shale ...	0	6		
23	**COAL** ...	1	7		
24	Shale ...	0	3		
25	**COAL** ...	6	0		
26	Shale ...	2	0		
27	**COAL** ...	7	6		
		——		22	6	151	0
28	Shale	2	6	153	6
29	Conglomerate ...	5	0	158	6
30	Gritty conglomerate	10	0	168	6
31	Grey shale	1	0	169	6
	No. 4 Coal-seam—				
32	**COAL**	1	0	170	6
33	Shale	1	0	171	6
34	Grits	7	0	178	6
35	Sandstone and grits...	5	0	183	6
36	Grey shale	2	0	185	6
37	Dark shale	22	6	208	0
38	Grit	0	3	208	3
	No. 5 Coal-seam—				
		Ft.	In.		
39	**COAL**, semi-bituminous	7	0		
40	**COAL**, bright	9	10		
		——		16	10	225	1
41	Sandstone and shale			2	2	227	3
42	Conglomerate ...			4	6	231	9
43	Gritty sandstone ...			0	10	232	7
44	Shale			0	2	232	9
45	**COAL**			3	10	236	7
46	Shale			0	4	236	11
47	Gritty sandstone ...			10	0	246	11
48	Conglomerate ...			1	0	247	11
	No. 6 Coal-seam—				
49	**COAL**			3	8	251	7
50	Gritty sandstone ...			0	4	251	11
51	Conglomerate ...					—	

No. 5.—No. 1 Prospecting Shaft on the Kromdraai Farm.

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
1	Soil	10	0	10	0
2	Sandstone	34	0	44	0
3	**COAL**	19	0	63	0

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No. 6.—No. 2 Prospecting Shaft on the Kromdraai Farm, 240 Feet away from No. 1 Shaft.

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
1	Soil	4	0	4	0
2	Sandstone	22	0	26	0
3	COAL	19	0	45	0

No. 7.—No. 1 Bore-hole, Blesboklaagte, near Witbank, 1897.

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
1	Soil	4	0	4	0
2	Sand and gravel ...	6	0	10	0
3	Coarse grit	4	0	14	0
4	Hard dry clay ...	8	0	22	0
5	Coarse grit	33	0	55	0
6	Micaceous shale and sandstone	7	0	62	0
7	Shale	16	6	78	6
8	Sandstone	0	6	79	0
	No. 5 Coal-seam —				
9	COAL ... F. 7	0			
10	COAL, splinty 1	6			
11	COAL ... 11	6			
		20	0	99	0
12	Shale	2	0	101	0
13	Grit	2	0	103	0

Mr. W. Pickstone said that there was plenty of coal in the Transvaal, and that the output would probably be increased rapidly within the next few years. Should, however, the labour question be settled on a sound basis by an influx of natives, or by the importation of Chinese, an output of £50,000,000 of gold might be expected within the next five or six years as compared with £15,520,329 at the present time; and, therefore, the coal-trade was likely to become good in the future.

Mr. W. H. Johnson asked whether the occurrence at the Apex mines was the only instance of gold and coal being found in the same area.

Mr. Sydney A. Smith said that in some districts the Coal-measures covered the gold-bearing rocks.

Mr. W. Pickstone moved a vote of thanks to Mr. Whitehead for his interesting paper.

Mr. Sydney A. Smith seconded the resolution, which was cordially approved.

Mr. Joseph Dickinson read the following paper on "Mountain Tunnelling":—

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MOUNTAIN TUNNELLING.

By JOSEPH DICKINSON.

Until within the last half-century, so far as the writer is aware, it was questioned whether the increase of earth-temperature under high elevations above sea-level agreed with the increase below sea-level. Now, it seems fairly agreed that the increase is similar, but that variations occur in each ratio. This confirmation has been obtained partly from observations in mining under high ground, and more especially in tunnels through the Alpine range.

Attention has recently been drawn to the subject by experiences in the Simplon tunnel, now nearly completed, through the Alps. *The Times* has had an article upon it;* and it has formed a topic in the address delivered by our President, Mr. John Gerrard;† and also in the address by Prof. R. A. S. Redmayne‡ before the South Staffordshire and East Worcestershire Institute of Mining Engineers; by Dr. Thomas Oliver;§ as well as in other quarters.

Increasing temperature with depth is so important in relation to mining operations, that a few additional observations may be worth recording for the benefit of our mining successors, who may have to deal with such phenomena.

The details given of the Simplon tunnel show that it is being constructed from both ends simultaneously: from Brigue on the Swiss side, with a gradient rising 1 in 500, and from the Italian side at 1 in 143; and that two parallel headings, with numerous cross-cuts between, have been driven from both ends. The driving from the Swiss side has been extended beyond the summit, leaving, in October, 1904, 810 feet to be executed before the headings meet.

* *The Times*, November 2nd, 1904, page 8, column 3.

† *Trans. Inst. M.E.*, 1904, vol. xxviii., page 365.

‡ *Ibid.*, 1904, vol. xxviii., page 37.

§ "A Visit to the Simplon Tunnel: the Works and Workmen," *Ibid.*, 1902, vol. xxiii., page 200.

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The summit from the Swiss side was reached without serious difficulty from drainage, though infiltrations amounting to 744 gallons a minute had to be dealt with, exclusive of the water artificially introduced for refrigerating appliances, rock-borers and other services. This driving has gone 2,658 feet beyond the summit, and in that distance embarrassing springs of water have been encountered, with a flow of 1,608 gallons a minute. This inflow, together with the water artificially introduced, amounts to 3,672 gallons a minute. The trouble of dealing with this inflow of water was further increased in the last 600 feet by 13 springs of hot water yielding 595 gallons a minute, the temperature varying from 104° to 117° Fahr. The men worked with waterproofs under the hot cascades, and the floor was submerged knee-deep.

The heat radiated by the rock through which the water flows, as measured in bore-holes about 5 feet in depth, amounted to between 97° and 99½° Fahr. and had to be kept down by great jets of water playing on the walls of the tunnel; and the temperature of the air was reduced to between 81° and 91° Fahr. by sprays of water—care also being taken to keep the water for cooling purposes as cool as possible, by running it in pipes lagged with broken charcoal in a casing of thin sheet-metal, as well as running away the escape-water in wooden casings, preferably to iron, on account of the non-conductivity of wood.

Since then, two other hot springs, yielding 480 gallons a minute, have increased the temperature, and the space for piping near the face being inadequate, the driving from the Swiss side has been discontinued. In this discontinued portion a large body of accumulated water is left to be dealt with hereafter.

Meanwhile, operations are being continued from the Italian side, where gravitational drainage is less difficult. Yet, even here, a hot spring, of 960 gallons a minute at a temperature of 114° Fahr., has been encountered.

It is supposed, from the variations of temperature, that the springs may not all be connected, but from the nature of the rock this is uncertain. It is hoped that more hot water will not be met with, and that the tapping of the accumulated water on the dip of the Swiss side, when the headings meet, will be the only remaining difficulty to be encountered.

The meeting of headings from entrances about 12 miles

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apart, and driven at different gradients, through a mountain-range, requires in itself fine engineering, irrespective of the other difficulties mentioned.

Mention has not been made as to the actual kind of rock met with in the Simplon tunnel. When the Mont Cenis tunnel was being driven through the Alps, the writer visited the face of the driving, about 3 miles in from the Savoy side. There was then a seam of coal between beds of Silurian-like rock. Other beds of similar coal had long been worked in the vicinity. A peculiarity that he noticed, in and out of the mines, was that the seams began in wedge-shape between enormous beds of rock, often swelling out, sometimes to 6 or more feet in thickness, and then they similarly tapered off and disappeared. Another peculiarity was that nowhere under the seams did he find any *Stigmaria ficoides*, such as occurs in the floor under coal-seams in British coal-fields.

A vote of thanks was heartily accorded to Mr. Dickinson for his paper.

Mr. Joseph Dickinson read the following communication on "Church in Mines."

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CHURCH IN COAL MINES.

By JOSEPH DICKINSON, F.G.S.

Recently an account came under my notice that "One of the most remarkable places of worship in the world" is the Miners' Chapel in Myndd colliery, near Swansea, where for more than half a century the workers have assembled each morning for worship.

The occurrence is unusual, but is not so remarkably isolated as supposed. In the early fifties of last century, when South Staffordshire formed part of my official district as inspector of mines, I found the custom followed in some of the collieries, it having commenced at a time of severe sickness. On one occasion in 1851, when I happened to be in the mine, the thick or 10 yard seam, I attended the service. It was reverently conducted. It was held mid-day at the time of the miners' luncheon or bait. In those days in South Staffordshire, beer was regularly allowed with the luncheon. Now both beer and chapel have been almost if not entirely discontinued in the mines.

A vote of thanks was accorded to Mr. Dickinson for his communication.

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MANCHESTER GEOLOGICAL AND MINING SOCIETY.

ORDINARY MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
JANUARY 10TH, 1905.

MR. JOHN GERRARD, PRESIDENT, IN THE CHAIR.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. ALFRED DAWES, Mine Manager, Llithfaen, Pwllheli, North Wales.
Mr. WILLIAM HORROBIN, Manager, Bedford Collieries, Leigh, Lancashire.
Mr. CHADWICK LORD, Manager, Jubilee Colliery, Crompton, near Oldham.
Mr. JOSEPH WATERWORTH, Manager, Westleigh Collieries, Leigh, Lancashire.

DEATHS OF SIR LOWTHIAN BELL, BART., AND MR. H. H. BOLTON.

The President (Mr. John Gerrard) called attention to the death of Sir Lowthian Bell, Bart., President of The Institution of Mining Engineers; and of Mr. H. H. Bolton, of Rossendale and Accrington, a very old member of the Manchester Geological and Mining Society, and a vote of sympathy and condolence with the relatives of the deceased gentlemen was passed in each case.

Mr. G. J. WILLIAMS (H.M. Inspector of Mines) read a paper on "A Safety-brake for Hand-cranes" as follows:—

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A SAFETY-BRAKE FOR HAND-CRANES.

By G. J. WILLIAMS.

In the North Wales quarries, especially in the slate-quarries, and also in the slate-mines, the so-called hand-crane almost universally employed is a four-legged derrick, which is used either for dragging heavy blocks of rock or for lifting them to a height and then lowering them on to a trolley or tram-waggon. Accidents with these cranes have been numerous and serious, often fatal, mainly through the handle flying back and striking a man on the head or face.

Fig. 1.—Lifting a Load with a Hand-crane: Ratchet and Pawl in Operation.

One of the Special Rules established under the Quarries Act requires that "every crane shall be provided with an efficient catch or an efficient brake." The cranes are generally fitted with a ratchet-and-pawl arrangement, which forms an efficient catch while a block is being raised, but as this must be thrown out of gear when lowering blocks, the remedy is but a partial one, and, in the writer's opinion, no mere catch can be efficient.

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Within the last 10 years several safety-brakes have been invented for these cranes, but none of them have been adopted to any large extent: partly, no doubt, because the workmen would not take kindly to them, as they involved additional labour.

The latest and the most suitable brake that the writer has yet seen is illustrated in Figs. 1 and 2. It is simple in construction; the inventors, whose sole object was the saving of life and limb, have not patented it, and it enables the user to do his work with greater ease. This brake is described in Mr. Henry Hall's Annual Reports for 1901* and 1903.† It was invented by Mr. John Jones, engineer at the Dinorwic quarry, and subsequently improved upon by Mr. John Jack, engineer at the Dinorwic quarry.

FIG. 2. LOWERING A LOAD BY MEANS OF THE SAFETY-BRAKE: PAWL THROWN OUT OF GEAR.

The brake has been designed to be worked on single-purchase for a load not exceeding 3 tons, and it can be fitted to any existing crane. In its present form, it consists of a ratchet-wheel and a small brake-wheel keyed to the shaft of the pinion-wheel; and, upon a crank-shaft placed above the pinion-shaft, are keyed a single-arm crank and a bell-crank. The pawl for holding the ratchet-wheel is attached to the single-arm crank by a pin-joint,

* Page 81. † Page 41.

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and the brake, for acting on the brake-wheel, is an iron or steel band lined with leather. The ends of this band, as well as the lever for actuating it, are attached by pin-joints to the bell-crank.

While the load is being lifted, it is checked and kept suspended by the ratchet-and-pawl, so that the handle cannot fly backwards. For lowering blocks of stone, the handles are removed, and the brake is then applied by means of the lever. The application of the brake automatically releases the pawl, which can be easily lifted up by the man applying the brake; a counterpoise, pinned to the pawl, keeps it in position, so as to be clear of the ratchet-wheel; and the load can be lowered at will, controlled by the brake.

It may be added that this type of brake is now used at the two largest slate-quarries in the world, employing about 5,000 men, and no mishap whatever has happened since its introduction.

There would be no difficulty in applying this brake to any pattern of crane.

Mr. G. J. Williams demonstrated the mode of working the brake, on a model.

Mr. W. Ollerenshaw moved a vote of thanks to Mr. Williams for his communication, and said that the fact that the brake was so largely adopted, was a proof that its use had passed the experimental stage. He was pleased to learn that not a single accident had occurred whilst using the brake at any of the quarries where it had been adopted.

Mr. George B. Harrison, in seconding the motion, said that many accidents had been occasioned, and sometimes lives were lost, for want of some means of protection such as this brake afforded. He was glad to know that it might be adopted freely, as it was not the subject of a patent.

The motion was cordially adopted.

Mr. A. J. Tonge asked, in the event of an additional shaft being used, so as to increase the power of the crane, whether the brake-arrangements were still retained, in the same form, on the first-motion shaft.

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The PRESIDENT (Mr. John Gerrard) asked whether the mechanism was applicable to any form of crane.

Mr. G. J. WILLIAMS stated that the safety-brake might be affixed to any crane. There was no increased friction of the gearing.

Mr. JAMES ASHWORTH's paper on "Outbursts of Gas and Coal at the Morrissey Collieries, British Columbia" was read as follows:—

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OUTBURSTS OF GAS AND COAL AT THE MORRISSEY COLLIERIES, BRITISH COLUMBIA.

By JAMES ASHWORTH.

Introduction.—Whilst the writer was in British Columbia a few months ago, Mr. R. G. Drinnan, the general superintendent of the collieries of the Crows Nest Pass Coal Company, Limited, favoured him with the particulars of unusually large outbursts of gas and small coal, in the No. 1 mine at Morrissey. The mine is situated about ½ mile east of the terminus of the Morrissey branch-line of railway, and about 4,000 feet above sea-level (about north latitude 49° 15′, and west longitude 114° 56′).

All the seams of coal worked at these collieries crop out at the surface; and at the No. 1 mine, the seam is a very soft, non-bituminous coal of irregular thickness, varying from 14 to 40 feet. The seam, dipping north-eastward at an angle of about 25 degrees, has a strong roof and floor. It probably corresponds with No. 61 seam, marked on No. 1 section of the Crows Nest Pass coal-field made by Mr. J. McEvoy.*

Three levels have been driven straight into the mountain-side, two of these serving as intake-airways, and the middle one as the return-airway to the fan. The lower level, the main haulage-road, entered about 20 feet above Morrissey creek and extended westwards for a distance of about 2,200 feet. It was cut in the top part of the seam, and had a rock-roof and a coal-floor. The ventilation of the mine was maintained by a fan, producing at the time of the outbursts about 60,000 cubic feet of air per minute, at a water-gauge of 0·75 inch. Three shifts of colliers were employed, and, although little or no gas was found in the mine, all the underground employees used Wolf safety-lamps (Fig. 1, Plate III.).

* "Summary Report on the Operations of the Geological Survey for the Year 1900," by Dr. G. M. Dawson, *Annual Report of the Geological Survey of Canada*, 1900, vol. xiii., section A, pages 84 and 95; "Summary Report on the Operations of the Geological Survey for the Year 1901," by Dr. G. M. Dawson, *Ibid.*, 1901, vol. xiv., section A, Nos. 759 and 767, maps.

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Outbursts.—(1).—On August 6th, 1903, about 2·30 p.m. and whilst work was proceeding as usual, the coal at the face of the main level commenced to emit sounds as if the mine would close up. It was deemed advisable to withdraw the men; but, before they were all out of the mine, an outburst of gas and coal occurred, which very quickly filled the whole mine with gas. So great was the force exerted by the pent-up and escaping gas, that small coal and dust were blown out of the mine, across the creek, and the ventilation was reversed. It was noticed that the water-gauge in the fan engine-house remained unaltered. No entrance could be effected into the mine, until four days after the outburst, although the fan was kept running at its highest speed. About 1,456 tons of small coal were loaded out of the main level, and 174 tons out of the parallel level before the faces were reached. For a distance of 150 feet outbye from the face, the main level was completely filled with dust and small coal; and not a setting of timber remained standing in that length. About half of the coal-pillar, on the higher side of the level, was removed for a distance of 100 feet outbye from the face (Fig. 2, Plate III.): D being the portion of the pillar that was blown off, and E a cavity, 8 to 10 feet wide and 110 feet long, that was blown out at the same time.

(2).—After this outburst, the greatest precautions were taken to guard against a possible recurrence, but, despite these, another outburst took place on October 14th, 1903; and although it displaced only about 800 tons of coal, and the gas was smaller in volume, yet it was more disastrous, because 4 men were smothered by the fine dust and gas. It was evident from the position in which the bodies were found, 2 hours after the outburst, that they had had some premonition of danger, and had moved away from their working-places. The quick recovery of the bodies was due to the reversal of the fan, which, as is usual in this district, could be quickly converted from an exhausting to a blowing fan by mechanical arrangements placed within the engine-house of the fan. This provision for changing the direction of the ventilating current may seem a little strange, but it is sometimes resorted to in the winter months, to assist in clearing away accumulations of ice from the main intake-airways.

Several outbursts of gas of small volume had, previous to that

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of August, 1903, occurred in the winning headings, but none had occurred in any other part of the mine.

The inspector of mines, in his annual report for 1903, wrote in reference to this mine, which he inspected every month:—"Notwithstanding the repeated outbursts of gas, I am bound to say that this mine could scarcely be put in better order. . . . They are working, in the first place, about 10 feet of the top. Ventilation is very good here; there are three connections with the outside, and they are making another near the face, where most of the men work, so that in case of an accident or outburst of gas the men in the upper workings will be almost outside. . . . . After one of these blowers has come away, it is quite a time before gas can be found in the mine."

(3).—An important precaution, which the management adopted, was to reduce the number of shifts worked to one in every 24 hours, so as to allow for gas-drainage, and for the following 13 months this appeared to have operated successfully; but, immediately after these notes were drafted, even this provision was found to be ineffective, and on November 18th, 1904, about 11·50 a.m., another huge outburst occurred, causing the deaths of 4 Englishmen, 10 foreigners and 2 mules.

The overman of the mine had just returned to the surface, after inspecting every working-place in the mine, and had found everything in its usual condition and not a trace of gas showing anywhere.

Only 1 man escaped from the mine: he was working at A, about 400 feet inbye on the main level (Fig. 1, Plate III.), when suddenly his lamp flared up and was extinguished, but this did not seem to have alarmed him, as he heard no unusual noise; he, however, felt as if something was catching his breath, and walked out of the mine to get his lamp relighted. Not until he saw a cloud of dust issue from the tunnel-mouth did he seem to have realized that anything was wrong. The dust found in the mine was as fine as flour, and that blown out of the mine with the gas was so fine that the men who saw it reported it as smoke.

For 35 minutes after the outburst occurred, it was impossible to approach any of the three entrances to the mine, although the fan was speeded to its utmost capacity; but after this interval

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the fan commenced to gain the ascendency, and the rescue-party were able to move slowly along the main tunnel. The first body recovered, that of a brattice-man, was found about 500 feet from the entrance. This man was on his way into the mine, and had put down his lamp upright on the floor, a little farther inbye. It is supposed, therefore, that after his lamp was extinguished by the gas, he had put it down and attempted to escape. No. 2 was a miner, who was on his way out of the mine before the outburst occurred, he had, in fact, just finished a cut-through at the level-face near Brindach's place. Nos. 3 and 4 were drivers with a mule, and they did not appear to have made any effort to escape, as the body of the mule was between them and heading into the mine. No. 5 was another driver, who appeared to have suspected that something was wrong, and had left his mule near where No. 12 body was found. Nos. 6, 7, 8, 9, 10, 11 and 12 appeared to have left their working-places all together, and made an ineffectual attempt to escape. Inbye from No. 12 body, the level was practically filled up with dust, there being only an open space of 6 to 8 inches near the roof. All these men were carrying their lamps, but from the position of some of them it was assumed that they were walking in the dark, and had all come from working-places near the face of the upper level. No. 14 was the only man who was fully dressed, and had his lunch-bucket with him. No. 13 was the body of Greenman, who was working in the main level, and it was his duty, if anything went wrong, to see that all men were out, and then to close the safety-doors, B and C, situated near No. 7 body. These safety-doors were hung on strong frames, and were held open by strings, so that, in case of danger, the last man could close them behind him, and thus prevent gas and dust from overtaking him before he reached the outside of the mine.

It is quite clear that the first warnings of an outburst were not so definite in character as on previous occasions, and that they were not sufficient, at first, to alarm the men seriously, several of whom had been present when previous outbursts had occurred, and who were always on the outlook for signs of unusual pressure on the coal. This outburst also differed from previous ones in the total absence of violence along the roads. A safety-lamp would fill with flame, 24 hours after the outburst, when held on the top of the fan-chimney, and a week

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afterwards there was a distinct cap on the lamp-flame in the return-airway.

The volume of air passing along the main level, as measured a few days before the outburst, was 57,000 cubic feet per minute, and the self-recording water-gauge, on the fan, showed absolutely no change during, before or after the outburst.

The mine had been shut-down for several months, and only a few places in the level-faces were being worked; and, for a month prior to the outburst, not a single report of gas had been made by the fireman.

The management estimate that this outburst displaced 3,500 tons of coal, 800 tons being removed to recover No. 14 body, which was found with fully 3 feet of dust under it, and it is supposed, therefore, that the man was wading through this depth of dust when he fell. One man, who was overtaken, was found in the attitude of running, upright on his feet, head leaning forward and hat on, and this fact, of itself, shows that there was no violence.

It is pretty clear from the foregoing particulars, that the men working at and near the face of the top level, received some warning before any check to the air-current could demonstrate to those on the road that an outburst was in progress, because they had run from 600 to 700 feet; whereas No. 5 had only run 500 feet, and No. 13, the same distance. Neither No. 1 nor the man who escaped appeared to have taken warning from the check to the air-current, as, had No. 1 done so, he ought to have escaped alive.

The check to the ventilation must, however, have been very severe, and its extent may be realized by noting that both of the intake air-currents were pushed towards the entrances of the mine, without the self-registering water-gauge in the engine-house of the fan showing any signs of increased pressure; and, therefore, it is fair to assume that the volume of gas given off must have exceeded 57,000 cubic feet per minute. Again, it may be noted that the volume of gas given off did not exhibit any signs of great violence, such as might have been expected if it had been suddenly released from a huge cavity. Nevertheless, it was enormous in volume, and continued at high pressure for 35 minutes, and at a diminishing pressure for a considerable time afterwards. It may, therefore, be reasonably supposed that

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from 2,000,000 to 3,000,000 cubic feet of gas, at atmospheric pressure, were set free by the outburst in 35 minutes. Mr. James McEvoy, who does not accept the cavity-theory, estimated the volume of gas at 5,000,000 cubic feet.

Remarks.—It does not seem reasonable to the writer to imagine that this tremendous volume of gas could be pent-up in a cavity in the coal-seam, and, taking into account the great quantities of dust, which have been a feature of all the outbursts in this mine, he has considered several probable solutions of the problem. In doing so, he has noticed that petroleum and natural gas are found in these Cretaceous measures; and also that on the south-eastern side of this coal-field seepages of petroleum have been found, and petroleum has already been and is still being sought in the Flathead district of south-eastern Kootenay.

The presence of petroleum in this district opens up the interesting geological problem of its source. Geologists state that there are no rocks in the district likely to contain stores of petroleum, but prospectors allege that there is visible evidence of its presence in several places. The late directors of the Geological Survey of Canada, Dr. G. M. Dawson and Dr. A. R. C. Selwyn, personally examined the district and identified the rocks as belonging to the Cambrian age, in which oil has never been found, as they are too close-grained and compact to be capable of absorbing oil. Dr. Dawson calls it "a somewhat anomalous occurrence of petroleum;" and if, as he suggests, these older rocks have been, by a gigantic overthrust, slipped eastwards over the Cretaceous formation, then the overthrust fault must extend from 10 to 12 miles eastwards. Mr. W. F. Robertson, the Provincial Mineralogist for British Columbia, states that seepages of oil occur in three or more places; that there might be a body of oil underground, but that this is problematical; and that, although some oil was found in a bore-hole at a depth of 1,120 feet there was no flow, and he is not sanguine that even at a depth of 3,000 feet a profitable flow of oil will be obtained.

The writer has referred to the oil controversy, because he thinks that the outbursts of gas referred to as having occurred at Morrissey may, and probably have, some connection with petroleum. The samples of oil obtained by Mr. W. F. Robert-

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son, and reported on by the Provincial Assayer, proved that the oils were of exceptionally low specific gravity: one sample consisted almost entirely of the lighter constituents of petroleum. It appears possible, and also probable, to the writer, that these frequent outbursts of gas may be attributable to the volatilization of light oil or spirit, which has been absorbed in patches of the soft coal, and, on being released by the removal or thinning of the surrounding coal, becomes volatilized with accompanying violence. As layer after layer of saturated coal is blown off, the dust is carried away by the gas, and the outburst continues until the oil-saturated mass is blown off and the oil or spirit volatilized. Under these conditions, the outburst would exert its greatest effect at the outset, and then gradually die away, as in the instances at Morrissey. If gas only were confined in a pocket, the writer does not see how so large a body of coal could be displaced; whereas, if a volume of oil were disseminated throughout a very soft portion of a coal-seam, which would, therefore, have the same absorbent qualities as a sponge, when the first burst occurred, the spongy coal would be carried away by the volatilization of the oil, and, as this proceeded, dust and gas would be continuously blown off, until the oil-saturated mass was exhausted. This supposition would allow of a very large volume of gas at high pressure being given off through a long period of time, and thus account for, what is at present, the mystery of the Morrissey outbursts. So problematical does the possibility of working the mine with any reasonable sense of security appear to the owners, that the writer understands that they have closed the mine.

In conclusion, the writer hopes that the subject may provoke discussion and suggestions from members, who may think that the mode of working, and the precautions taken to guard against such outbursts, can be so effectively improved, that the further working of the mine may be rendered reasonably safe.

The PRESIDENT (Mr. John Gerrard) said that in 1893* Mr. Joseph Dickinson read a paper on somewhat similar outbursts; and in 1899† he (Mr. Gerrard) read a paper describing the outbursts which caused such sad loss of life at the Broadoak

* *Trans. M.G.S.*, 1893, vol. xxii., page 239.

† *Trans. Inst. M.E.*, 1899, vol. xviii., page 251.

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colliery, Ashton-under-Lyne. Having felt the responsibility of that anxious time, he could deeply sympathize with those having the charge of the Morrissey mine and he hoped that they might be enabled to prevent further loss of life.

Mr. ARTHUR MILLER said that, for 10 years, he was manager of the Broadoak colliery, which was specially liable to this class of outburst, and he appreciated the anxieties of the managers of the Morrissey colliery. The outbursts at the Broadoak colliery were not on so large a scale as those mentioned, but they were the cause of several fatal accidents. He recommended the managers of the Morrissey colliery to adopt the precautions which were found to be effectual at Broadoak colliery. The plan was to bore holes into the soft coal, from which the outburst came, and thus afford the gas a safe outlet. The coal was particularly soft in places, and contained large volumes of gas. When the hard coal had been worked away, and the soft coal was reached, a sudden outburst took place. This was obviated by boring, in advance, into the soft coal, and gradually liberating the gas. He thought that the best remedy would be to work the seam on the longwall system, if possible, with a wide face. The warnings used to be given by sharp knocking sounds, like the firing of a company of sharpshooters. When a fault was crossed, a bore-hole was made as soon as there was room, and more holes were drilled as the work proceeded. In this way, serious outbursts of gas were prevented. When he (Mr. Miller) took charge of the Broadoak colliery, Mr. Gerrard advised that bore-holes should be made; and the suggestion was adopted and continued until the mine was abandoned about a year ago.

Mr. HENRY BRAMALL said that he had been troubled with outbursts in the Rams mine, at Pendleton colliery, at depths varying from 2,500 to 3,500 feet; and he had not been able to account for them on any theory that had yet been broached. In his case, the characteristics were similar to those at Broadoak colliery, with the exception that gas was not given off. He was, therefore, at a loss to understand the cause, unless it were due to the great pressure bearing upon the coal. He suggested that the coal in certain places was different in its texture from the rest, and when the workmen had driven a place through one of those portions, which they call "hard knots," they had

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suddenly released the support, and the pressure on the face had brought on an outburst of coal crushed into dust as fine as soot. On one occasion, so large a body of dust came out that it saturated the air in the return-airway and was carried to the shaft, a distance of 7,200 feet: the incline, for 6,000 feet, rising about 1 in 3. The pressure, causing the outburst, must have been very great, and the quantity of dust must have been very great also. Fortunately, they had never lost a life, nor had a man injured. He did not think that gas had played any part in the outbursts at Pendleton colliery, so that he was thrown back on the only other reason to account for them, and that was the extreme pressure due to the depth of the mine.

Mr. CHARLES PILKINGTON asked what kind of a roof there was on the coal. Possibly both the roof and the floor were very smooth, and, if so, that might, to some extent, account for the large quantity of stuff thrown forward. It used to be the fashion to pierce very gassy mines with narrow places, but that could not be done in all cases, and no doubt the only practicable plan was to make bore-holes in advance, as suggested by Mr. Miller. The bore-holes might be kept, say, 60 feet in advance of the face, and, say, 150 feet apart.

Mr. ARTHUR MILLER said that the distance of the bore-holes was a question for the engineers to decide for themselves. It was best to err on the side of having too many bore-holes, and to drive them far enough in advance. In his case, three bore-holes were made in a place, 45 feet wide, and they were always kept at a minimum length of 5 feet in advance; and more bore-holes were driven in the leading roads.

Mr. CHARLES PILKINGTON suggested that the coal might be blown out, if the holes were only 5 feet long.

Mr. ARTHUR MILLER said that it was possible to tap a place that relieved the pressure in a very large area. In the case of the last serious outburst at Broadoak colliery, when 3 men were killed, the area, although it was a large one, was not all open in front. The men were driving a level and the soft coal blew out of a narrow aperture. One could not say, therefore, how many, or how far the bore-holes should be in advance: that could only be determined after careful consideration of the circumstances. The greatest width of the cavity was 30 feet, and

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the soft coal had been blown through an opening, about 3 feet wide. In ordinary cases, the cubic measurements of the cavity corresponded with the amount of material blown out.

Mr. George B. Harrison said that he had examined the cavities in the Broadoak colliery, and he was very much struck with their shape and size. There had evidently been great force; and the dust seemed to have come out of the softer portions of the coal-seam. In company with Mr. Miller, he had heard the indication which had been mentioned, but at that time there was no sign of gas. The men persevered with a bore-hole until it had penetrated the disturbed area, and then gas came off freely, so much so that they had to retreat. In the course of a few minutes, they were able to return, and, on again examining the bore-hole, he was surprised to find that it had been enlarged by the escaping gas sufficiently to enable him to insert an upright safety-lamp. The mine was deep, but the pent-up gas seemed to play an important part in producing the outbursts at Broadoak colliery.

Mr. Miller asked whether there was any intimation of weight on the roof at the time of the outbursts at Pendleton colliery.

Mr. Henry Bramall replied that there were indications of weight. The discussion had shown, to some extent, the difference between the outbursts at Broadoak and Pendleton collieries. In the latter case, nothing of the nature of a cavity was created and no gas was found, hence the outburst was solely due to the pressure on the face. The coal-face had been crushed into very fine dust, and generally behind that there had been a very "hard knot"—very hard and tough to get. Assuming the occurrence of a pocket of very soft, porous coal, saturated with gas under great pressure in a surrounding mass of hard coal, it was only a question of time until the surrounding wall of hard coal was sufficiently thinned and weakened for the gas to burst out and bring with it all the soft coal in a disintegrated form. The outbursts at Pendleton colliery were due to pressure; and those at Broadoak colliery were probably due to pent-up gas under enormous pressure, and probably contained in a pocket of soft coal saturated with gas. Then, although the hole made into such a pocket may be only 3 feet wide, it may bring out all the soft coal

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and leave a large cavity behind. At Broadoak colliery, the gas was liberated by drilling; but at Pendleton colliery, drilling would be of no use. The mine is worked on the longwall system.

Mr. A. MILLER remarked that no outburst had occurred at Broadoak colliery where the roof was badly broken.

The PRESIDENT (Mr. John Gerrard) said it was proved, in the case of Broadoak colliery, that changes occurred in the strata and that frequently, before an outburst occurred, the mining portion of the seam was more clayey and less coaly; the stratum was hard. The small bore-holes frequently became choked, and they were more beneficial when the diameter was increased to about 3 inches.

Mr. J. ASHWORTH, replying to the discussion, wrote that the outbursts at Broadoak, Pendleton and Morrissey collieries had their separate and distinct characteristics, and were, therefore, of their kind, typical examples of these undesirable occurrences. The Morrissey mine differed from the others in that it had no hard coal; in fact, he did not think that it made any round coal at all. Since the last outburst, the mine had been closed, as there was clearly no known mode of working the mine, which would offer adequate security for the miners' lives. Mr. Miller and Mr. Pilkington had overlooked the fact that the No. 1 mine at Morrissey collieries was very thick, that nothing but narrow work was being driven in the mine, and that the levels were being driven in the top part of the seam close to the roof. Had the mine been still at work, he would have suggested that one level should be driven at the top of the seam with a rock-roof, and the other level close to the floor, so that the cut-throughs would intersect the seam from top to bottom. The character of the last outburst at Morrissey collieries did not give him (Mr. Ashworth) the impression of pent-up gas, but rather of a liquid volatilizing and throwing off layer after layer of oil-saturated fine coal. The levels had not been cleared up to the faces, and, therefore, no information could be given of the character of a possible cavity; but the cavity found after the outburst of August, 1903, was shown in Fig. 2 (Plate III.).

A hearty vote of thanks was accorded to Mr. Ashworth for his interesting paper.

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PART III. VOL. XXIX.

TRANSACTIONS

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FEB 2 1910

MANCHESTER GEOLOGICAL AND MINING SOCIETY.

ORDINARY MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
FEBRUARY 14TH, 1905.

MR. JOHN GERRARD, PRESIDENT, IN THE CHAIR.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. YOSHIMA SAIKE, Mining Engineer, Jagawa Colliery, Buzen, Japan.

Mr. KICHIRO TAKAGI, Mining Engineer, The Miike Collieries, Chikugo, Japan.

MR. HERBERT TATLOCK WILKINSON, Electrical and Mechanical Engineer, 78, King Street, Manchester.

Mr. JAMES ASHWORTH'S "Notes on the Crow's Nest Coalfield, British Columbia," were read as follows:—

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NOTES ON THE CROW'S NEST COAL-FIELD, BRITISH COLUMBIA.

By JAMES ASHWORTH.

Crow's Nest Coal-field.—The Crow's Nest coal-field is situated immediately west of the summit of the Rocky Mountains, about 370 miles from the Pacific coast, and practically the whole of it lies in British Columbia. The coal-field is of Cretaceous age, and the rocks of this section cover an area of about 500 square miles; but the coal-field has an area of only about 230 miles and is of leg-of-mutton shape, with a length from north to south of about 35 miles, and a width from east to west varying from 4 to about 11 miles. It is bounded on the west by the Elk river, which runs parallel to the upturned edges of the measures, and the outcrops of the coal are found commencing at an elevation of from 1,500 to 2,000 feet above the river, with a dip to the eastward of from 20 to 40 degrees. The coal-field is in the shape of a flat-bottomed basin, and the coal therefore crops out with its upturned edges to the north, south, east and west.

The coal-field is based on the Devono-Carboniferous limestone, and in ascending order, from this base, there are beds of dark shale and soft calcareous shales, known as the "Fernie shales," which have been much crushed and folded. The coal-seams above have not, however, been affected to the same extent, particularly on the west and south sides, and it has been assumed that the very hard beds of conglomerate (consisting of black and grey chert, embedded in a silicified matrix) and gritty sandstone (shown at the top of the section of the Morrissey coal-field, made by Mr. James McEvoy),* have resisted the eroding, crushing and folding forces that are in evidence elsewhere.

* "Summary Report on the Operations of the Geological Survey for the Year 1900," by Dr. G. M. Dawson, *Annual Report of the Geological Survey of Canada, 1900*, 1903, vol. xiii., section A, page 87; and *Ibid., 1901*, 1904, vol. xiv., section A, Nos. 759 and 767, maps.

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The total thickness of the Cretaceous rocks in this coal-field has been estimated at from 12,000 to 13,000 feet, and in the section before referred to, there is a thickness of about 198 feet of workable coal in a depth of 1,847 feet of strata. Seams of 3 feet and under are omitted from the calculation.

Only a very few years ago, the Crow's Nest coal-field was a *terra incognita*, and the first reference made to it was in the report of the Geological Survey of Canada, 1880-1882. Subsequently to this and for some eight years it was persistently prospected by Mr. William Fernie (after whom the town of Fernie is named), and during this period (1889-1897), a syndicate was formed to develop, what Dr. Dawson called "one of the most remarkable coal-basins known." In the latter year, an arrangement was made with the Canadian Pacific Railway Company for the construction of the Crow's Nest Railway from Dunmore to Kootenay Lake, a distance of 394 miles. The Crow's Nest Pass Coal Company, Limited, was incorporated by Dominion charter in 1897, and now owns 250,000 acres of land. This company has opened mines at Michel at the northern end, at Carbonado (Morrissey) at the southern end, and at Coal Creek (Fernie) in the centre of the western side. The Canadian Pacific Railway Company and other companies own coal-lands in this area, but nothing more than exploratory work has been done up to the present time. The railway-track reached Fernie in 1898, and the output of coal has been increasing year by year, until it is now equal to about 5,000 tons per day; and the coke-production amounts to about 1,500 tons per day.

Samples of the seams of coal collected by the inspectors of mines gave the following percentage-analysis:—Moisture, 0·91; volatile combustible matter, 19·01; fixed carbon, 69·93; ash, 9·83; and sulphur, 0·32. The coke made from these coals is long, lustrous and strong, and is shipped to the smelters in Canada and the United States, *via* the Canadian Pacific and Great Northern railways.

At Coal Creek and Carbonado, the valleys are so narrow, where the mines are opened out, that the coke-ovens (bee-hive) are placed at some distance from the mines; but at Michel, they are close to the works.

A peculiar legislative restriction is placed on the Crow's Nest Pass Coal Company, by which they are prevented from charging

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more than 8s. 4d. (2 dollars) per ton for run-of-mine coal at the mines.

Most of the coal-seams are soft, and produce a large proportion of small slack.

The seams of coal, now being developed in several places, have not been absolutely correlated, but Mr. J. McEvoy places Nos. 61, 63 and 71 in his Morrissey section, as being the same as the three seams of coal at Coal Creek, which are respectively 10 feet, 30 feet and 6 feet thick. No. 61 seam will therefore correspond with the Fernie mine (Coal Creek, No. 2), in which the explosion occurred in 1902; and with No. 1 mine, Carbonado, where the huge outbursts of gas occurred.* Although the thicknesses of the coal-seams are much the same at both places, the intervening strata have thinned to the north, thus, 140 feet and 197 feet, or a total of 337 feet, become 60 feet and 42 feet, or a total of 102 feet, showing a reduction of 235 feet. It would seem that this thinning process is continuous in a northerly direction, and in the Frank-Blairmore coal-field (adjoining the Crow's Nest coal-field on the north, and divided from it by the main range of the Rocky Mountains), the productive thickness of the Lower Cretaceous measures is placed by Mr. W. W. Leach at 740 feet, with 125 feet of coal, thus showing a great thinning of both coal and shale.

Frank-Blairmore Coal-field.—The Crow's Nest and Frank-Blairmore coal-fields are practically one coal-field separated by great upheavals, foldings and crushing of the strata.

From the "Loop," say, 3 miles east of Michel, the Devono-Carboniferous rocks forming the eastern boundary of the Crow's Nest coal-field, are in evidence nearly as far as the eastern end of the Crow's Nest Lake, where there is a faulted contact with the Upper Cretaceous and Laramie measures. These measures continue for the next 4 miles, and are followed by beds of volcanic ash, agglomerates and Flathead shale beds, for 1¼ miles, until the Lower Cretaceous coal-measures are again met with near Coleman. From Coleman to Frank, the coal-field is very much disturbed, and at Frank the limestone is pushed right through the coal. At the western contact of these strata, there is a wellknown sulphur-spring, and at its eastern contact the

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 56.

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coal-measures are turned up, and, in fact, partly turned over by the limestone-upheaval. This vast intrusion of limestone on the north side of the railway is known as Bluff Mountain; on the south side as Turtle Mountain; and the space between, through which the railway passes, is known as the Gap. For about 4½ miles east of Frank, the coal-measures are disturbed and folded, and a fault forms the contact with the coal-seams and lignites of the Upper Cretaceous and Laramie measures. The Upper Cretaceous coal-seams have been opened up to only a very limited extent.

One of the most noticeable of the great disturbances and movements of enormous masses of limestone-rock in this district is clearly demonstrated by the position of the Crow's Nest Mountain, perched on the Upper Cretaceous measures, about 4½ miles north of the railway. This mountain is unclimbable by most people, but during last summer Mr. Edward Whymper's party succeeded in planting a flag-staff and flag on the summit. Mr. Whymper described it as the driest mountain that he had ever climbed, as it was devoid of either water or snow.

Other notable disturbances are common in the Alberta district of Canada, and an instance, near Banff, may be interesting, as the coal-measures there are based on the limestone and also covered with limestone, and the coal-seams are both bituminous and anthracitic.

Rock-slide at Frank.—At Frank, where a huge rock-slide occurred about 4 a.m. on April 29th, 1903, the coal-measures, as previously noted, have been cut through and tilted by the limestone forming Bluff and Turtle Mountains. An adit-level has been driven into the coal near the foot of Turtle Mountain, by the Canadian American Coal Company, Limited, to a coal-seam, from 12 to 16 feet thick. Extraction of coal by this level commenced in 1901, and developments had been carried out so vigorously from that date up to the time of the accident that the output had reached 600 to 1,000 tons per day. The main level had been driven 5,600 feet, and some of the rooms had been worked up nearly to the outcrop. The precise height of the mountain above the valley does not seem to have been known, but it was probably about 2,500 feet. There were no premonitory symptoms of a fall, and work was proceeding as usual at the

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mine. A train of loaded cars had just been drawn out of the colliery-siding, when, about 4 a.m., a fearful rumble was heard, and the eastern face of the mountain slid down into the valley with enormous velocity. The only living witnesses of the fall were the train-hands. All the men engaged at the colliery-tipple, the cars, staging, machinery, coke-ovens and dwelling-houses with their inmates, were swept away in a moment, and of the 83 people, known to have lost their lives, only 6 bodies were recovered. No one who has not been to the place and walked over the fallen mass of stone, and seen rails on end and other materials just showing above the débris, can form any adequate idea of the occurrence, and no photographs can do more than give a vague idea of the vast mass or sea of broken stones, which covers 900 acres of ground. A length of two miles of the Canadian Pacific railway-track was completely buried, and a mile or more of the Grassy Mountain railway. The brakeman and operator of the train, which had just pulled out of the colliery-siding, were the first men to cross the fall, and they did so to stop a passenger train and thus avert further disaster. The débris, as it lies in the valley to-day, gives a spectator the idea of a huge wave breaking on the sea-shore, with two gigantic petrified billows occupying about the centre of the valley, and the broken water (of stones) running up Bluff Mountain on the opposite side of the valley, to a vertical height of 250 feet above the original valley.

At the time of the disaster, 19 men were engaged in the mine, 17 of whom saved themselves by digging a way out; but the other 2 are supposed to have been out on the tipple, and to have been swept away with the staging and machinery. The men who escaped, on getting out, said that their first intimation of something having gone wrong was a "surging of the hanging-wall, and a crushing or falling of coal all around them," giving them the idea that an explosion had occurred.

So far as the writer knows, it is still an open query as to what set 500,000,000 cubic yards of limestone-rock in motion. Several theories have been propounded, one of which was that there had been an earthquake, but there does not appear to be anything to support this suggestion, any more than that at Lille, 4 miles to the north, and at Blairmore, 2 miles to the west, people were awakened out of their sleep by the noise and shock

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of the falling mass. Another theory was that water, formed from melting snow, had found its way to the base of the mountain and had thus formed a slippery bed, over which loosened rock, pressed down by the superincumbent mass above, commenced to move, and thus brought about the fall. It was also suggested that a hard night's frost, following a warm opening day of spring, was the force which set the mass in motion. Many other theories have been suggested, but they are quite outside the possibilities of the occurrence. The writer thinks, as the Cretaceous rocks had been weakened and broken by upheaval and exposure on both sides of the outcrop of the coal-seam, that the removal of the coal had the same effect as taking out a sprag from underneath the foot of Turtle Mountain, and that the movement was thus originated. It may be observed, however, that the damage done within the mine was very slight, excepting near the entrance.

The adit-level has now been reopened, and a pit has been sunk near the Gap; and supposing that the working of the coal-seam from the adit-level was the disturbing cause of the disaster, it appears possible, if not probable, that at some future date the disaster may be repeated, and the whole of the remaining portion of the town of Frank might be swept away. The number of empty houses in the town is sufficient evidence to a stranger that the miners of the district have not recovered sufficient confidence in the stability of the face of Turtle Mountain, to take up their residence beneath its shadow.

In conclusion, the writer acknowledges the courtesy and valuable information and assistance he had received from Dr. Robert Bell, director of the Geological Survey of Canada; Mr. James McEvoy, geologist to the Crow's Nest Pass Coal Company, Limited, and late of the Geological Survey of Canada; Mr. Frank B. Smith, inspector of mines for the North West Territories; and Mr. O. E. S. Whiteside, of Blairmore.

A vote of thanks was passed to Mr. James Ashworth for his paper.

Prof. W. Boyd Dawkins said that he had seen some of the coal-seams in the region referred to, not far from the Rocky

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Mountains. An enormous deposit of coal exists in the Cretaceous rocks, and when he was there about 15 years ago they were boring, and had discovered two thick seams of coal. A blower of gas, coming up one of the bore-holes, became ignited and destroyed the shaft. Thereafter the gas was used, instead of coal, for driving the boring machinery. The Crow's Nest coal-field is of vast importance, and it is extremely interesting from the fact that in some places where the pressure and the crushing have been very great, the coal, described as a coking coal, is converted absolutely into an anthracite. The local heat, resulting probably from enormous local pressure, had driven off the volatile material and left the carbon in the condition of anthracite.

Mr. JOSEPH DICKINSON asked whether the mine at Frank was stowed with rubbish, so as to support Turtle Mountain. The land-slide seemed to have been a serious matter, something like the movement of the bog in Connaught of late. There were two ways of working mines: one was by temporarily supporting the face of the workings, and allowing the ground behind to fall; and the other way was to build up pack-walls to support the roof, and allowing the ground to subside gradually. The absence of pack-walls at Frank might have helped the mountain to slide down; and, seeing that the people had not got over their terror, it might be desirable to put them on their guard against the danger that arose through not building supports.

The PRESIDENT (Mr. John Gerrard) said that two years ago, an interesting report by Messrs. R. G. MacConnell and R. W. Brock was issued by the Canadian Government on the subject of the huge slide at Frank.* The main fact that he gathered from this report was that the mine was little disturbed, except near the entrance. It was a most extraordinary disaster, involving great loss of life and huge devastation.

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* *Report on the Great Land-slide at Frank, Alta, 1903.*

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MANCHESTER GEOLOGICAL AND MINING SOCIETY.

ORDINARY MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
MARCH 14TH, 1905.

MR. JOHN GERRARD, PRESIDENT, IN THE CHAIR.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. J. U. ROGER GRAVE, Civil Engineer, 32, Northfield Terrace, Eastmoor Road, Wakefield.

Mr. FRANK PERCY, Mechanical Engineer, 3, Springfield Street, Wigan.

Mr. JAMES ASHWORTH's description of "The Hunter V. Mine, British Columbia," was read as follows:—

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THE HUNTER V. MINE, BRITISH COLUMBIA.

By JAMES ASHWORTH.

Aerial Cableway.—The Hunter V. and Double Standard claims, belonging to the British Columbia Standard Mining Company, Limited, are located on the top of a mountain near Ymir, and may be reached either by aerial cableway, horseback or on foot. The writer, with three others, took the cableway, starting from the Canadian Pacific Railway.

This aerial cableway, being one of the most recently erected in British Columbia, may be safely assumed to exemplify some of the best points in this mode of transportation. The distance between the terminal stations of the main cableway is 13,000 feet, and there are in addition two supplementary cableways, 1,800 and 500 feet long respectively. All three are worked separately, entirely by gravity, and the speed is regulated by powerful brakes on the clip-wheels at the upper stations.

On the main cableway, the top or fixed ropes, $1\frac{1}{4}$ inches in diameter, are in two lengths, the first being anchored at the top station (Fig. 1), and tightened from time to time as required at a station about midway (Fig. 2). At this station, the bottom length is also anchored, and is tightened, as required, at the bottom terminal station (Fig. 3).

On the Hunter V. cableway, the longest length between the supporting towers is about 1,800 feet, and the height above the ground is about 300 feet.

The haulage-rope, $\frac{3}{4}$ inch in diameter, is an endless rope. The buckets, of which there are 30, are placed at equidistances apart. When the rope is running at the rate of 400 feet per minute, 100 tons of ore can be easily transported and delivered into cars on the railway, in 10 hours; and this quantity can be increased by adding extra buckets.

Special cradles are used for carrying men and timber: two of these cradles being placed a short distance apart, so that the

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timber, in transit, is supported at both ends, and, therefore, rides practically horizontally.

Every movement in the loading and unloading of the buckets, is, as far as possible automatic: thus, starting from the bottom station (Fig. 3), the catches which fasten the bucket in position when loaded, are opened by a fixed disengaging arrangement (Fig. 4), and the bucket (say, No. 26) dumps its contents into the ore-bin without a stop, and then, passing onwards round the return-wheel, continues its course back to the

FIG. 1.—TOP STATION OF THE MAIN CABLEWAY: THE ORE-BIN BEING FILLED BY THE SUPPLEMENTARY CABLEWAY.

mine with the bucket in an inverted position. The object of running the inverted bucket is to prevent water or snow from filling it whilst in transit. On arrival at the top station the bucket strikes an inclined-plane arrangement (Fig. 5), which forces the bucket into its proper position and allows the catches to close on to the hooks, and it is then ready for loading on the other side of the clip-wheel. Here a man, by means of three levers (Fig. 6), regulates the loading and the movements of the main cableway. In the intervals of time, between the buckets passing

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this point, the man opens the shoot, A, close at his left hand, and fills the automatic loader, B, shewn below. On the arrival of a bucket (say, No. 23), a catch on the hanging frame of the bucket engages with a bar on the loader, B, and takes it in tow, and then the loader automatically discharges its contents into the bucket, while still in motion. The loader, after traversing a certain distance (Fig. 7), disengages from the bucket, and is brought back to its original position, by a counterbalance-weight, ready for loading from the bin. The ore-bin is filled

FIG. 2.—MIDWAY ANCHORAGE OF THE MAIN CABLEWAY.

by the supplementary cableway, and the buckets are dumped automatically (Fig. 1).

The buckets at the top and bottom stations (Figs. 4 and 5) are run from the cable on to fixed edge-rails, which conduct them round the clip-wheel and the return-wheel. Fig. 8 shows a line of derricks where the line makes a curve over one of the hills, and also shows an inverted bucket returning to the mine. The return-wheel (Fig. 4) is mounted on a movable platform, by means of which, and a heavy counterbalance-weight, the haulage-rope is kept in tension. The flanged wheels (Fig. 5) are

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made in halves, so that the tread of the wheel, which is a separate part, and is fixed in position by molten lead, may be removed and replaced, without the expense of having an entirely new wheel.

FIG. 3.—BOTTOM STATION OF THE MAIN CABLEWAY.

This mode of transportation can be applied for the cheap transit of ore and materials over long distances, and for heavy outputs. Another aerial tramway, under erection, has a length of 3½ miles, and a capacity of 800 tons per 10 hours; and another

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one, 4½ miles long, demonstrates that long and continuous lengths can be worked by this system, without its being necessary to place the ropes in one straight line. This mode of transportation being simple in its details, the movements being as far

FIG. 4.—INTERIOR OF THE BOTTOM STATION.

as possible automatic, and the working power being gravity, it is obvious that the cost per ton of material moved is very low.

When the writer travelled on this cableway, the time occupied in the transit to the mine, which is at an elevation of 5,500 feet above sea-level, was about 50 minutes.

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Hunter V. Mine.—The Hunter V. group of claims includes, within its boundaries, portions of a limestone-deposit, the extent of which has not yet been fully ascertained. Locally, it forms the upper portion of the mountains near the head of Porcupine

FIG. 5.—INTERIOR OF THE TOP STATION.

Creek, in the Ymir district. In the company's claims, the deposit is in the shape of a tongue, about 2,000 feet wide, and several miles in length. It is surrounded on three sides by a more or less altered gabbro of later origin, and belonging, it is

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thought, to the Carboniferous age. The gabbro cuts into the limestone in places, whilst in others the limestone appears to be entirely surrounded by igneous rocks, just as if portions had become detached from the main mass, and had floated off into

FIG. 6.—LOADING SIDE OF THE TOP STATION.

the molten magma. No fossil remains have been discovered so as to establish definitely the age of the limestone.

Where least disturbed, the bedding planes strike in an east-and-west direction, and dip slightly to the south. In the process

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of mountain-building, the mass has, like many other parts of British Columbia, been subjected to great strains, with the result that in places it is faulted, folded and contorted into confusing shapes, and the original structure is almost entirely obscured.

FIG. 7.—LOADING SIDE OF THE TOP STATION.

Fractures have also been formed, in which the circulating waters have re-deposited the lime as pure calcite, and these occur in irregular bands throughout the mass, varying in thickness up to 6 or 8 feet. At some other period, siliceous solutions appear to

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have circulated throughout the formation, and silica has been deposited in the free state, as also in combination with lime, magnesia, etc.

The most conspicuous minerals that have been found are tetrahedrite (grey copper), zinc-blende, galena, pyrites and native silver.

The origin of the mineralization has not yet been determined, but it will no doubt be traced to the more recent eruptive rock surrounding it, and near the contact of which the largest mineralized areas have been discovered. It appears, however,

FIG. 8.—CURVED LINE OF DERRICKS.

as an impregnation in the limestone-deposit, and no lines can at present be laid down to trace it to its source, because irregularity of occurrence, and indefiniteness of shape, appear to be its chief characteristics.

The mineralization is more evident on the surface, in the bedding planes of the limestone, which the decomposition of the grey copper often colours green, whilst crystals of azurite are frequently seen scattered along these lines of enrichment

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Native silver, in leaves or plates, is more particularly met with on the faces of joint-planes, and may have been reduced and deposited there through the agency of surface-waters containing organic matter. Planes of fracture are common, some showing incipient movement and others none, but they appear to have an important bearing on the deposition of the ore, for in many cases it is found to be richer on one side of such planes than upon the other.

The opening of the mine has been principally confined to two areas, one on the Hunter V. claim, at the top of the hill, where the face of the quarry at present shows a width of over 70 feet of ore; and the other on the Double Standard claim, 1,400 feet distant, and vertically over 400 feet lower down the hill, where the Glory Hole is more than 120 feet wide, showing mineralization from side to side. Other outcrops of mineral have also been discovered on various parts of the property, though not at present opened up.

This deposit of limestone is unique in the district, and until it is further explored, a more comprehensive study of the occurrence cannot be made.

When the quarries are more fully opened out, the ore will be delivered into railway-cars at a cost of 4s. 2d. (1 dollar) or less per ton.

The ore, up to the time of the writer's visit, averaged about 13 per cent. of silica and 44 per cent. of lime; at times, the silica had run as low as 9 per cent., and the lime had risen to 48 per cent.; but experience had shown that an increase of silica did not necessarily mean a proportionate fall in the percentage of lime. These figures show that this ore is a valuable flux to the smelters. The ordinary limerock, which is used by the various smelters as a flux, when delivered at Nelson or Trail, costs about 6s. 3d. (1½ dollars) per ton, and at Northport 2s. 8½d. (65 cents.) per ton; and such limerock contains about 48 per cent. of lime and 8 per cent. of silica.

In what form the gold and silver are combined has not yet been determined, excepting so far as the native silver, and the silver contained in the grey copper, are concerned. The gold-contents have proved to be relatively higher in the Double Standard than in the Hunter V. claim, and it is in the former that the most siliceous material has been found

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Conclusion.—These few notes would, the writer thinks, be incomplete, without a reference to the excellent food provided at the mining camps, fully equal to an average hotel; and the cook, particularly if he happens to be a white man, receives a much higher salary than a good clerk will receive in this country. A white cook, who satisfies the miners, is a valuable acquisition both to masters and men.

At some camps, which are in a sense out of touch with civilization, there is no actual observance of Sunday, because it has been found that its non-observance is a lesser evil than idleness.

The writer's thanks are particularly due to Mr. N. Carmichael, Mr. J. J. Campbell, Mr. J. Johnson and Mr. W. S. Riblet for the technical details recorded in this paper.

Mr. WILLIAM SAINT, in moving a vote of thanks to the author of the paper, said that the installation of aerial rope-haulage was on a very large scale, and there were few opportunities of studying the practical side of the question in Great Britain. There were two small installations in Lancashire: in each of those cases the endless rope travelled and carried the loads; but in that of the Hunter V. mine, probably owing to the steeper inclinations of the hills which were traversed, the carrying ropes were fixed, and these were supplemented with an endless haulage-rope to which the loads were attached.

Mr. H. STANLEY ATHERTON, in seconding the motion, remarked that he had seen an aerial rope at work similar to that described in the paper, but on a smaller scale. The longest of those that he had seen was 7,000 feet.

The motion was unanimously adopted.

Mr. GEORGE H. WINSTANLEY read the following paper on "A Fatality caused by Low-pressure Electric Current in a Lancashire Colliery":—

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A FATALITY CAUSED BY LOW-PRESSURE ELECTRIC CURRENT IN A LANCASHIRE COLLIERY.

By GEORGE H. WINSTANLEY.

Introduction.—In the course of the discussion upon Messrs. Philip C. Pope and Norman D. Cameron's paper,* the writer was impressed by the illustration introduced by Mr. Pope, with reference to the relative dangers of high-tension and low-tension electric currents. The writer already held similar views on the subject, but the singularly apt illustration had not occurred to him. It will be remembered that Mr. Pope expressed the opinion that, although high-pressure current was generally supposed to be more dangerous, as a matter of fact the greater proportion of accidents, serious and fatal, were in connection with low pressure. Mr. Pope suggested, in explanation of this, that where the danger is of, say, a mild nature, where the risks of fatal results are supposed to be small, an amount of indifference and carelessness results, not to say negligence, leading workmen to do things, and incur risks, which they would never dream of doing where the danger is great and the result certain destruction. The illustration used by Mr. Pope was that afforded by a level-crossing on a railway: with a train some distance away one would not hesitate to cross the line, with something approaching carelessness in the act. But if the train, an express rushing along at 60 miles an hour, is only a few feet away, one would never attempt to cross the line until the train had passed: to make the attempt would, of course, be to meet a positively certain and violent death.

It would appear that an element of danger, once recognized, becomes its own safeguard against accident. It is not considered necessary to fence the edge of a railway-station platform, although it may be occupied by numbers of people, whilst trains are rushing through at high speeds. It is not even con-

* "Practical Comparisons of Continuous-current and Polyphase Electrical Systems as applied to British Collieries," *Trans. M. G. S.*, 1904, vol. xxviii., page 652.

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sidered necessary to warn people that they must not stand in front of the trains, nor on the edge of the platform.

Unfortunately, in connection with electrical matters, people cannot always be got to recognize, as they should, that electricity, like other forms of energy, must be treated with a certain amount of care; and still more unfortunately, when anything does go wrong, it does not seem to occur to anyone to attach the blame to anything but to the electricity.

The writer thinks it is unfortunate that the new regulations seem to convey the impression that low-pressure current calls for less stringent measures than medium or high pressures. It ought to be clearly understood by all those who have in any way to use electricity in mines, that electricity is dangerous, whether it be generated and used at 100 or at 10,000 volts. A current at a pressure of 100 volts has been known to kill; and current at 10,000 volts can do no more. In the one case, there may be a doubt as to the result, but in the other there can be no doubt. With a low-pressure current, although scores of people can speak to receiving shocks at 100, 200, 300, 400, 500 volts, or even higher (the writer has had 10,000 volts) without serious results, still the doubt is there, and one ought to take the benefit of the doubt, and avoid the risk of a shock at any pressure.

It should be clearly understood that although the pressure determines the amount of current which may pass through the body of a person receiving a shock, it is not the pressure but the quantity of current that kills: not volts, but ampères. The writer is not sure what current will prove fatal, but he believes that it is only a very small fraction (3/1,000) of an ampère. Generally speaking, the resistance of the human body being high, a low pressure is not capable of passing even this small current and the shock is neither serious nor fatal. Everything, however, depends upon circumstances, and it is quite possible that the conditions under which a person receives a shock, may be such that a sufficient current may pass to produce fatal results, even with a low pressure.

The circumstances favourable to a fatal shock at a low pressure would seem to include the following:—A moist state of the skin, a large area of contact, and the length of time during which the person remains in contact. The physical condition of

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the person no doubt has a considerable influence, although in the case, hereinafter described, the man was perfectly strong and healthy in every respect.

Some few years ago, one of the writer's students was killed by a shock from a circuit at 100 volts. In that case, the unfortunate young man had only shortly recovered from a serious illness.

The Accident.—A fatal accident occurred at the Bower colliery, in June, 1904.

The installation at Bower colliery is a small one: the full-load capacity being about 30 electric horsepower. The generator is a six-pole continuous-current belt-driven machine, giving at full load, 93·25 ampères and 240 volts, at 475 revolutions per minute. It had, however, never been worked at full load, the total capacity of the underground plant being about 8 horse-power, namely:—A 5 brake-horsepower motor, working a three-throw pump, with rams 5 inches in diameter, and a small motor of about 3 brake-horsepower, working a small pump, with rams 2 inches in diameter.

It was from the cables conveying current to the last-named motor, that the man received the shock, which resulted in his death. The motor required current equal to 1 horsepower only, and the conductor used was a single strand containing seven wires of No. 20 standard wire-gauge. The lead and return cables were both placed on the same side of the road, they were armoured with galvanized wire, with the armouring left bare; and both cables were secured to the road-timbers by means of porcelain insulators.

This, no doubt, was an error of judgment. In connection with electrical appliances, one ought to be guided by expert advice, and installations should certainly be carried out by skilled electricians. Ignorance of important electrical principles, as in this case, may lead to serious results. No doubt it was considered, in so small an installation as this, at a low pressure, that expert assistance was unnecessary. The writer is well acquainted with the manager at this colliery, and has a high opinion of his abilities as a colliery manager. He is fully alive to the dangers attending colliery working; he would not knowingly allow anything to jeopardize the safety of the men

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under his charge; and the writer has rarely met with one more zealous in making provision for the safety of his mine. The very circumstances which have been described seem to indicate on the part of someone, a desire to take what appeared to be every precaution. The writer feels it to be only fair to make these remarks, because he is anxious to avoid the appearance of attaching blame to anyone; and because the manager himself has been only too willing to place at the writer's disposal all the details of the case.

The provision of armoured cables was considered a measure of safety, and the securing of those armoured cables to porcelain insulators was meant to be a further safeguard. Unfortunately, lack of expert knowledge obscured the fact that what was meant as a safeguard, was really a source of danger. Armoured cables, with the armouring properly earthed, would have been comparatively safe, but armoured cables on porcelain insulators actually became bare live wires. Joints had been made in these cables, they had not been made by experts, and the electrical continuity of the armouring had been broken. If cables are armoured, the electrical continuity must be maintained; and where joints have been made, the armouring must be coupled as well as the conductor. In the case at Bower colliery, the joints had not been perfectly made; and, somehow, the armouring wires had made contact with live wires, so that the two cables became, to all intents and purposes, bare wires carried on porcelain insulators.

Wilfred Smith, the victim of the fatal accident, was a man of 26 years of age, strong and healthy. He was employed in connection with the haulage, in the brow down which the cables were taken to the small motor. The mine is wet and warm, and the inclination steep. Smith was naked from the waist upward, and at the moment of the accident had previously run some distance up the steep brow, to assist in lifting certain tubs, which had run off the rails. He was, at the moment, perspiring freely, as the result of his exertions in the warm and moist atmosphere, and possibly his heart would be pulsating vigorously after hurrying up the brow. Stepping back to allow the tubs to be drawn up, he stumbled and fell with the broad of his bare back against the two cables. Here were all the conditions favourable for a fatal shock, particularly a moist skin and a large area

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of contact. At the moment of the accident, the deceased made a single exclamation and became unconscious. He was pulled away, and according to those who were present appeared to live for several minutes, during which time they attempted to restore respiration.

The foreman of the coroner's jury, which enquired into the cause of death, was the late Mr. W. W. Millington, and it was a matter of considerable regret that the writer found himself called upon to do what Mr. Millington had undertaken, namely, to bring the facts of this accident before the members. The inquest was attended by Mr. Gilbert Scott Ram, a Home Office electrical expert, who, with our President, Mr. John Gerrard, investigated the circumstances very minutely.

Mr. Gerrard then expressed the view, which the writer had always held, never more strongly than now, that one must not differentiate where electricity is concerned, at least in the direction of lessened precautions, whether the pressure be high or low; and electrical appliances for use in mines must be of the best. Officials and others, whose duties involve the use or control of electrical appliances, must possess a knowledge of electrical principles; and that knowledge must not be acquired experimentally, by doing things on the wrong lines until a fatal accident convinces us that the system is wrong. Engineers must make it their business to acquire that knowledge by a careful study of those principles: they are well enough known, and there is little excuse for ignorance on the subject. Only too much, in the past, have engineers relied upon what some people choose to call "practical experience," by which they mean the discovery that a certain procedure was dangerous, after it had been responsible for loss of life.

Mr. Joseph Dickinson, in moving a vote of thanks to Mr. Winstanley for his instructive paper, said that the Home Office were now issuing Special Rules to collieries on the subject. When he read them he thought that they were very lengthy, but from what Mr. Winstanley had now laid before the members their length really appeared to be justified. They were divided into as many as 11 sections, in addition to the definitions. The

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latter served a double purpose in defining the different pressures: 250 volts being low pressure; from 250 to 650 volts, medium pressure; from 650 to 3,000 volts, high pressure; and anything beyond 3,000 volts, extra high pressure.

Mr. T. H. WORDSWORTH, in seconding the motion, said that he had listened with very great interest to the paper affording information respecting the accident at Bower colliery. He believed it was a recognized law of Nature that "length of time compensated for lack of intensity of action," and engineers should not expect that law to be broken in the case of electricity. If a low pressure were applied for a long time the result would be the same as from the application of a high pressure for a short time; and the fatality, which Mr. Winstanley had described, should make every engineer cognizant of the fact that low pressure had its dangers as well as high pressure.

The resolution was unanimously adopted.

Mr. ALFRED J. TONGE said that it had been pointed out by several of the witnesses before the Departmental Committee, appointed to enquire into the use of electricity in coal and metalliferous mines, that the high pressures in use on the Continent had not proved so prolific in accidents as the low pressures in use in this country. These witnesses spoke largely from the same standpoint as that taken by Mr. Pope, in the paper which he and Mr. Cameron recently read to the members, namely, that workmen were more afraid when they knew the pressure was high, and they kept at a greater distance from it on that account. He (Mr. Tonge) thought that much might be said in that regard; but he could not altogether agree with Mr. Winstanley, when he said that all was quite plain and straightforward as regards minimizing the dangers. There were many electricians, who did not recommend the earthing of the armouring of cables, and so according to some of them, the manager, at Bower colliery, would be doing the right thing in what he did; personally, he held the opposite opinion, but it was difficult to act contrary to the advice of a skilled electrician. Where two cables were used, one would always be more liable to go wrong than if the concentric system had been used. He (Mr. Tonge) thought that justice was scarcely done to the concentric system. The Departmental Com-

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mittee had simply permitted its use, without apparently going into the real question as to how far it might be governed. The only regulation in the Special Rules is, that where the concentric system is applied, sufficient precautions shall be taken to safeguard it. He thought that from the standpoint of the safety of the workmen, who are not employed directly with the electrical plant—the men working on the roads, or the colliers passing along with their tools—the concentric system was the safest and best. There might be practical difficulties with it at the coal-face, where the electricity is being used; but, on investigation, it would be found that very largely underground accidents occurred on the roadways to men who were not, for the time being, directly employed at the electrical plant, and, therefore, the system that seemed safest to the great bulk of the men, should be considered. He (Mr. Tonge) thought that it would have been better to have stated in the different clauses of the Special Rules of the Departmental Committee what precautions should be taken in regard to the definite pressures of 250 volts, 650 volts, etc.; rather than define the pressures as low, high, or extra high. There would then be less tendency for any workman to imagine that a low pressure was comparatively safe, and a high pressure very dangerous.

Mr. S. E. Bastow said that he was constantly in touch, in various ways, with electricity, and perhaps it would interest the members to know what effects various shocks had had upon him. He had, under some circumstances, been unable to sustain a shock of 2 volts; although, under favourable conditions, he could withstand a shock of 60 volts without serious inconvenience. On another occasion, with his fingers soaked in acids and lead salts, he found that he could not do so. In the case of the deceased man, Wilfred Smith, there was a broad surface of contact with the wire, and he had taken the full voltage through his body. Probably, he received some considerable fraction of an ampère through his body. It was estimated that 3/1,000 ampère was fatal. It should not be forgotten (as Mr. Winstanley had stated) that it was not voltage that causes death: it was the amount of current through the tissues of the heart that killed, and the amount just mentioned would cause serious lesions of the heart. In the case in question, the man's skin being moist, it would offer a low resistance, and he might receive

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½ ampère through his heart. That was the cause of death and not the usual shock, for the man was able to speak and lived for some time after the shock, although his friends were not able to restore him. Instances had occurred of persons receiving a pressure of 2,000 volts, and becoming unconscious. He had had that experience, and came round naturally without artificial respiration. Take the analogy of a rifle-bullet: if the velocity be high and the bullet small, the missile may go through a man's heart without killing him; but if a bigger bullet be used at a slower speed, the result would be death. It was the same with electrical energy: low pressure with broad and long contact would cause death; but at the same time, he did not agree with all that had been said about the relative dangers of high and low pressures. He thought that Continental experience had not extended over a sufficiently long time to prove the extra safety of the high-pressure system. Naturally, the use of a high-pressure system tended to greater caution on the part of the men; but it was possible that high pressures might cause faults in the system, that could not be easily foreseen, and they might cause accidents. He (Mr. Bastow) disagreed with Mr. Tonge as to the use of concentric cables: a motor might be used at a long distance from the generating plant, and when the current was shut off from the motor, a serious shock might be received from the cable. The shock was due to the capacity of concentric cables, and unless it was kept extremely low, it would be a source of danger. In his own case, he had had to handle switches connected with long lengths of concentric cables: on one occasion he took hold of one, and received such a severe shock that he was propelled across the station.

The PRESIDENT (Mr. John Gerrard) said that when on the Continent recently, he saw a notice-board containing a representation of forked lightning drawn across it in red paint and the following words: "Nicht berühren! Hochspannung! Lebensgefährlich!" The interpretation is as follows: "Do not touch! High tension! dangerous to life!" If such notice-boards were used in connection with electrical appliances in this country, it would be infinitely more serviceable than writing in chalk the word "danger." In electrical works in Germany, copies of Dr. Sylvester's method of restoring the victims of shock were posted, in the same way as, in other places, illustrations of the methods

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for the restoration of persons apparently drowned were posted up. He had been told that there were better methods than Dr. Sylvester's; and he asked whether someone would tell the members what was the best method of attempting to restore persons suffering from electric shock. Mr. Winstanley was most kind in his reference to the manager of Bower colliery, who had charge of the men working in that mine and who deeply felt this sad accident and loss of life. There was one point in the paper that he would venture to criticize, and that was with reference to imposing the whole of the responsibility for the selection of the plant upon the manager of the colliery. The manager would not claim to be an electrical engineer; he would, probably, consult an electrical engineer; and he ought not to have suggested such an application of electricity as that which caused this sad fatality. The members were all anxious to use this new and convenient power, if it could be used with safety.

Mr. PHILIP C. POPE said that, when a man was installing a small electrical plant, he did not often realize that there was as much danger attached to a small as to a large installation. It was only a question of the length of contact, and of the man's condition at the moment to determine the result of contact. If a pressure of 1,000 volts for ½ second was too much, an equally bad effect would be produced by a shock of 500 volts extending over double the time: that was not the exact proportion, but it was approximately true. Much depended on the resistance of individual bodies: a very severe shock to one man might be a trifling one to another, and in his (Mr. Pope's) opinion, it mattered not how small the installation or how low the voltage, the same precautions should be taken in every case to ensure freedom from accident. He was very glad to see, from the Special Rules issued by the Home Office, that the earthing of wires and the due protection of machines would be enforced. Irrespective of the size of the plant, it should be properly installed in the first instance, and there would then be no difficulty afterwards.

Mr. G. H. WINSTANLEY, replying to the discussion, said that it was gratifying to find that Mr Bastow and Mr. Pope so completely endorsed his attempt to bring home the importance of seeing that electricity was only used under safe conditions.

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DISCUSSION OF MR. J. ASHWORTH'S PAPER ON "OUTBURSTS OF GAS AND COAL AT THE MORRISSEY COLLIERIES, BRITISH COLUMBIA."*

Mr. J. ASHWORTH wrote that he had received the following information from Mr. Frank B. Smith, inspector of mines for the North West Territory, respecting outbursts of gas in his district. At Canmore, in the same coal-field as Banff, there had been several outbursts of gas, but of much smaller volume than those at Morrissey, and on April 9th, 1903, two men were suffocated by one of these outbursts. To guard against such outbursts as far as possible, the following precautions had been adopted, namely, (*a*) to keep a bore-hole ahead, and (*b*) to work the places as wide as possible.

At Medicine Hat, North West Territory, a town standing on Upper Cretaceous measures, bore-holes had been put down to tap the natural gas. One bore-hole, over 900 feet deep, supplied the town with light and fuel, and another (which had lately been put down by the Canadian Pacific Railway Company to a depth of 950 feet, to supply their repair-shops) found gas on January 25th, 1904, at a pressure of 25 pounds per square inch. The pressure and the volume of the gas did not, however, remain constant and continued to increase until, in ½ hour after being struck, it had reached a pressure of 445 pounds per square inch. A coal-seam was passed through at a depth of about 100 feet, but he did not know whether the gas came from the Upper or from the Lower Cretaceous measures.

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* *Trans. Inst. M. E.*, 1905, vol. xxix., page 56; and *Trans. M. G. S.*, 1905, vol. xxix., page 66.

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The entire Series of the Geological Survey Maps on the one-inch and six-inch scale, with Memoirs, of the Lancashire Coal Field, is now complete, and available for reference by the Members.

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PART IV. VOL. XXIX.

TRANSACTIONS

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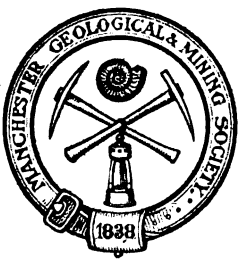
EDITED BY

THE HONORARY SECRETARY.

SESSION 1904-1905.



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MANCHESTER GEOLOGICAL AND MINING SOCIETY.

ORDINARY MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
APRIL 11TH, 1905.

MR. JOHN GERRARD, PRESIDENT, IN THE CHAIR.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. P. B. COULSTON, Mechanical and Electrical Engineer, 5, Cross Street, Manchester.

Mr. REUBEN H. HARVEY, Electrical and Mechanical Engineer, Anchor Cable Company, Leigh, Lancashire.

Mr. THOMAS SCHOLES, Colliery Manager, Oswaldtwistle Collieries, Oswaldtwistle, Accrington.

Mr. JOHN WALSHAW, Colliery Manager, Astley and Tyldesley Collieries, Tyldesley, Manchester.

CAPPING OF WIRE-ROPES.

The PRESIDENT (Mr. John Gerrard) exhibited a solid form of wire-rope capping, cut across so as to shew a sectional view of the wires embedded in a composition of white metal. He desired to call the attention of the members to the serious difference which was frequently found between the strength of wire-ropes and their cappings. He mentioned the question now, so that it might be considered, and at a subsequent meeting the members might give their experiences and express their views on the subject. The capping of ropes, for some years, had received his (Mr. Gerrard's) consideration, and it was alarming to find that there was such a difference between the strength of the cap and the strength of the rope, in a great many of the cappings in use. The loss of strength was as great as 50 per cent., that was to say, there was often a factor of safety of 10 to 1 in the rope and of only 5 to 1 in the capping. As

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the strength of a chain was that of its weakest link, so the strength of a winding-rope was no more than the strength of its capping. Mr. F. L. Ward, mining engineer of the Bradford colliery, had given much attention to the question of improving the form of the cap; and, as the result of long-continued experiments, he had succeeded in making a cap which was equal in strength to the rope.

DISCUSSION OF MR. J. ASHWORTH'S "NOTES ON THE CROW'S NEST COAL-FIELD, BRITISH COLUMBIA."*

Mr. JAMES ASHWORTH, replying to Mr. Joseph Dickinson, wrote that the coal-seam at Frank is practically vertical above the adit-level, and the mode of working is a mixture of longwall and pillar. Two rows of pillars separate the rooms, which are possibly 180 feet wide, and are kept full of mined coal, and only as much coal is taken out by shoots into the pit-wagons at the foot of each room, as is necessary to allow room for working. The men reach the working-faces by manways in the pillars between the rooms, and these pillars are the real supports of the wastes, together with the loose coal.

It seemed probable that the masses of rock pressing against the unsupported vertical side of the coal-seam, caused it to bend or break and thus, so to speak, loosened the sprag, which held up the mountain-side. If this took place, it is conceivable that the effect on the mine would be as described by the men who escaped, and the noise, within the mine, might only be equal to that of a muffled and heavy weighting of the roof, as experienced in a thick mine of a flat or moderate inclination. Some of the rooms were worked within a short distance of the outcrop, and the strata were sufficiently soft for the men to work their way out without much difficulty.

Mr. ARTHUR ROSS read the following paper on "The Circulation of Water in Steam-boilers":—

* *Trans. Inst. M. E.*, 1904, vol. xxix., page 330.

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THE CIRCULATION OF WATER IN STEAM-BOILERS.

By ARTHUR ROSS.

For at least the last 100 years, the circulation of water in steam-boilers has engaged the attention of engineers and boiler-makers, yet the accumulated knowledge of these years has still left plenty of room for additions to the stock of information, although boiler-design has varied almost to bewilderment. Mr. N. P. Hugh, in *A Treatise on Boilers*, remarks that, up to 1873, there were no less than 3,000 patents for steam-boilers, and doubtless since that date some thousands of additional applications have been filed.

Boilers are naturally listed for all practical purposes under two main types, namely, (1) fire-tube, having fire inside the tube; and (2) water-tube, having water inside the tube. The opinions of experts still differ so widely, each side having so many good arguments for the defence of their particular type, that the writer does not propose to discuss the merits or shortcomings of any boiler in particular, but rather to exhibit some details touching the question of circulation, which is more or less common to every type of boiler.

Engineers agree that an efficient circulation means a greater efficiency of the steam-generator, and to this conclusion they are led by the natural movements which follow the application of heat to a fluid or gas, and possibly solids also.* Water follows the almost universal law that the absorption of heat expands a body and after expansion it will weigh less per unit of volume. In other words, each unit is lighter, in proportion to the heat absorbed, and the warm molecules of water rise, by virtue of their lower specific gravity, thus making room for the heavier and colder molecules to fall and touch the source of heat, till they too, having taken in as much as makes them appreciably lighter than the upper particles, also want to reach the top.

* These movements are termed "convection-currents."

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This movement is the result of under firing, but should the heat be applied at the top it would take a very long time to raise the temperature of the lower water, and even then it would mainly be done by conduction through the outside shell. The warm molecules once on the top have no inclination to vacate that position voluntarily (Fig. 1, Plate XXIV.). Exactly opposite effects result from opposite treatment, and by applying cold to the upper layer of water, convection-currents are started downward, the result of their greater specific gravity (Fig. 2, Plate XXIV.).

Figs. 1 and 2 (Plate XXIV.) represent two copper vessels, *a*, similar in all respects, except that one is surrounded by a gas-ring, *d*, and the other by a freezing mixture, *e*. On watching the thermometers, *b* and *c*, the temperature will rise rapidly at the top thermometer, *c*, of the heated tube (Fig. 1) while the lower one, *b*, keeps stationary. The effect of the freezing mixture will be demonstrated by the fall of temperature at the bottom thermometer, *b*, till 40° Fahr. is attained, and then the thermometer, *c*, will take up the running and the temperature fall, while the bottom thermometer, *b*, remains stationary.

The writer will presently show how these facts bear upon steam-boilers, but in nature they are of the utmost importance. For instance, although by the waves of the sea, the tides, and the flow of rivers, considerable heat is absorbed from the sun, yet, if heat were conducted rapidly downward, it would probably kill all aquatic organisms; while, on the other hand, if cold were allowed to have continued sway, then by convection-currents, cold water would descend, and ice would first form at the bottom. As heat convection-currents will only rise, then open waters would always remain frozen at the bottom, until finally there would be a return of the ice age. The expansion of water is an exception to the rule, since water attains its greatest density and minimum volume about 40° Fahr., so that still colder water, between 40° and 32° Fahr., floats on the surface instead of falling to the bottom, and ice is formed on the surface instead of at the bottom. These natural currents cease to act when the water is nearly of an even temperature throughout: for instance, a general ebullition of steam kills all other movement; then there is plenty of disturbance, but no circulation of water over the heating surfaces.

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Convection-currents, therefore (useful though they be), cannot alone be depended upon for efficient circulation. Even in the old under-fired boiler, when steam is formed, there is an end to all true circulation; and, if the water is heated above the bottom, as in Lancashire and Scotch boilers, the warm convection-currents will not move downward, as every observer of the temperatures at the bottom, when lighting up, is fully aware.*

As convection-currents are always slow and weak, failing to operate when aggressive steam-bubbles appear, one must ascertain whether it is not possible to obtain the desired circulation in some other way. In this case, as in all other operations of any kind whatever, nothing can be done except by the expenditure of work or its equivalent in heat. Even convection-currents obey this rule, as the warm current on rising loses heat, until the whole of the water attains an equal temperature. Hence, the operation must be conducted in such a manner that the profit is a large one; some work must be spent to gain greater heat, otherwise it is outside the realms of practical consideration.

Let it be understood that by efficient or real circulation, is meant a movement of the water over the heating surface of the boiler. Other movements or disturbances there may be; but such a flow is only of value when it tends to absorb more of the provided heat of the fire; and other movements may even have a wasteful effect, unless carefully guarded.

It is not necessary to demonstrate the advantages of a moderate circulation of the water over the heating surface, as there cannot be two opinions on this point, although there are differences of opinion as to the value of a high rate of movement. Some experiments seem to show that, after a critical speed is reached, there is a rapid fall in efficiency;† and the writer hopes to investigate this point at an early date.

To imagine the operation of steam-formation, one must con-

* *Manchester Steam Users' Association: Report on a Series of Red-hot Furnace Crown Experiments, to ascertain the Result of Injecting the Feed-water into a Boiler when short of Water and with Fires burning*, by the Chief Engineer, Mr. Lavington E. Fletcher, 1890, pages 48 to 50.

† "Experiments on the Heat-absorption Power of Water," by Mr. George Halliday, *Transactions of the Institute of Marine Engineers*, London, 1899, vol. xi., No. 84 paper, page 17.

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sider a particle of water, which occupies only a very small volume: on absorbing sufficient heat, it is turned into steam and occupies many times its original volume, varied according to the steam-pressure, until it becomes large enough to overcome the pressure of the layers of water above it. The disturbance that it causes at the place of generation is very small: the greatest movement occurs in the upper layers of water; but these layers do not lie on the heating surface, and, as shewn in Fig. 1, (Plate XXIV.) they do not flow downward. Consequently, they do not assist in a real circulation. The physical changes, occurring when water leaves the fluid for the gaseous state, are still shrouded in mystery; and it may be that, when a workable theory of this wonderful change is propounded, one will know better how to make water absorb heat, and to build boilers accordingly. At present, it is known that the change does take place, but by no means free of cost. Were it not for the marvellous energy stored up in steam, it would be useless for present applications; and it is this heat-absorbing capacity which one must nurse and feed, for, by the proportion of heat that can be transferred from the fuel to the water, the efficiency or otherwise of the steam-generator will be judged.

Fig. 3 (Plate XXIV.) represents two vertical glass tubes, *a* and *b*, $\frac{3}{4}$ inch in diameter, connected at their bases, by a copper tube, *c*, and attached at their upper ends to a tank, *d*. Fig. 4 (Plate XXIV.) is a single glass tube, *a*, 2 inches in diameter, the base being closed by a copper cap, *b*, and heat is applied from a gas-ring, *c*. From experiments with these appliances, the writer draws the following conclusions:—

(1) A small quantity of water placed in the single tube (Fig. 4) will demonstrate how steam frees itself under atmospheric pressure, when the layer of water on the heating surface is thin.

(2) The layer of water being increased in depth, it is evident that the steam has more difficulty in shaking off the superincumbent weight of water. The conclusion to be deduced from this fact is that, having once produced the bubble of steam, one must not hinder it from getting free of the covering water, and no possible advantage can be derived by opposing the natural action of the steam to free itself: it is wanted for use, and it should be afforded as easy a passage as possible. This experiment seems to indicate that the Lancashire type is prefer-

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able, on this point, say, to a Belleville boiler, as the water over the crown of the furnace of a Lancashire boiler is generally less than 1 foot deep; while in a Belleville boiler the steam-bubble must traverse 100 to 160 feet of pipes before it is free. The writer does not think that the necessity for allowing steam to shake off the water, as quickly as possible, has been realized by the later designers of boilers. A bubble of steam cannot squeeze through 10, 20 or more feet of water, without losing some energy, a loss which does no useful work.

(3) As steam is formed in the double tube (Fig. 3), a reciprocating motion will be produced, governed by the formation, condensation or discharge of steam at the base. Some such action is likely to ensue when the tube-ends are not covered with water, as in the case of some types of boilers. It will also be noticed that the steam-bubbles form plugs, easily in the small tube (Fig. 3), but not so easily in the large tube (Fig. 4); though doubtless there would be a similar action in a large tube, if sufficient fire were applied. It may also be noted that the plugs of steam do not "entrain" the water as has so frequently been described; the action is rather a slipping of the steam past the water, the large tube (Fig. 4) clearly demonstrating the same action. Steam does not carry the water along, although it might blow out a small quantity at the tube-end: the bubble elbows itself into a front place, just as a constable forcing himself to the front through a tightly-packed crowd. Taking any particular section of water, it seems to remain continually in about the same position, while steam is being regularly formed.

(4) When the double tube (Fig. 3) is filled with water, circulation is set up; and it is noticeable that, although the bulk added is but small yet the radiation of heat, by circulation, is so great that it will take a long time to bring the water to the boil, and even then ebullition will not be so rapid. This lesson proves that radiation must be checked to the greatest possible extent; and although the correctness of Newton's law that "the transmission of heat is in direct proportion to the difference in temperature," is being largely questioned, so far as the absorbtion of heat by water is concerned; yet there can be no possible doubt that heat falls out of carefully-made steam very rapidly and upon every possible occasion.

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Figs. 5 and 6 (Plate XXIV.) represent a model of an ordinary Lancashire boiler, heated with gas-fuel. The tubes, *a* and *b*, the smoke-box, *c*, the chimney, *d*, and the enclosing-case, *f*, are made of copper; and the boiler-shell is made of glass. This model demonstrates how steam-bubbles leave the furnace-tubes, and, at the same time, the position on the tubes, from which they rise, can be noted.

Fig. 7 (Plate XXIV.) illustrates the apparatus used in an experiment intended to show the flow of circulation, and to demonstrate the possibility of dry tubes, when the fire is at its highest. This model of a water-tube boiler consists of two vertical glass tubes, *a* and *c*, connected by an inclined copper tube, *b*, and attached to the tank, *d*. The experiment tends to demonstrate that downcomers and risers should, at least, be of equal capacity with the steaming tubes and that a slight constriction, in either the inlet or the outlet, may be bad for the tubes. If it is not possible to provide a corresponding down tube for each uptake tube, then the capacity of the downcomer should be equal to the sum of the volumes of all the uptake tubes. Even this precaution will not entirely obviate the trouble when boilers are forced, but the liability to serious damage is not so great, as the dryness of the tube is momentary; while, with a constricted end, the pipe may be dry for an appreciable period. During the time that steam fills the tube no circulation is possible, and a careful watching of the model will demonstrate this at once.

Mr. J. I. Thornycroft stated, some years ago, in his paper on the "Circulation in the Thornycroft Water-tube Boiler," that "I have recently made experiments on the relative circulation of boilers when the generating tubes deliver above the water in the separator and below it, and I have found that, in the case where they deliver above, the circulation is rather more than double that when they deliver below."* The arrangement suggested by Mr. Thornycroft, for delivering the generating tubes above the water-level is a good one, as it offers little or no hindrance to, but rather acts as a suction upon, the return-supply; and it is more likely to create a real circulation of the

* *Transactions of the Institution of Naval Architects*, 1894, vol. xxxv., page 289.

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water, than in boilers where the steam is constantly struggling to overcome the head of water in the top drum: this being the case in several types of boilers. This model also shows that convection-currents can be utilized, so that the natural movement is aided and maintained. Messrs. Yarrow & Company's experiments* showed that the addition of heat increased the rate of flow.

The tubular models therefore demonstrate that:—

(1) It is possible to raise the speed of the circulation by enclosing and guiding the natural convection-currents.

(2) The upflow and return tubes should be made of equal size.

(3) There is considerable danger of restricting the upflow or return, either by using smaller tubes or by the deposition of scale.

(4) It is a question whether the long distance through which the bubbles of steam have to travel is not a disadvantage.

(5) Although the circulation may be rapid, yet as the tubes are partly (or at times wholly) full of steam, they are then not so efficient as when full of water, because a gas is a worse conductor of heat than a fluid; and steam will absorb less heat from the fire. Hence, all possible efforts should be made to keep the water, as solid as possible, upon the heating surfaces.

(6) To obtain the very highest results, water must always be solid over the heating surfaces, and the layer of water should be thin, so as to allow of the free egress of the steam.

It may be asked, if circulation be so very important and valuable, and seeing that water-tubes seem to provide the most suitable form, why they are not used to the exclusion of all others. To reply fully to this question rather takes us outside the subject of this paper, but a few remarks may be made: (1) As soon as the strictest simplicity of design is departed from, there always arises a great array of structural troubles, and boilers are no exception to this rule. To the purchaser this means a considerable annual charge, either for repairs or for extra labour in cleaning, joint-making, etc. (2) The question of large brick-furnaces is a serious one, both from the standpoint of

* *Engineering*, 1896, vol. lxi., page 39.

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maintenance and that of efficiency as compared with a water-surrounded furnace. And (3) the point arises, whether flames or gases, striking outside a tube full of water, have as efficient heating effect as a tube full of flame wholly immersed in water. These considerations weigh less heavily in cases where space and weight are not of such vital importance as in torpedo-boats, and the like. Under the usual industrial conditions, the evaporation per pound of fuel is much the same in the large tube-type and in Lancashire boilers; and it is probable that the great gain, obtained by rapid circulation, is largely lost in the extensive brick-furnace, which has to be kept at a great heat, and the greater ease with which gases escape round the outside of a tube, without parting with their heat.

In boilers of the Lancashire type, the principal source of heat is surrounded by water, instead of surrounding the water, as in a water-tube boiler; the bulk of water is considerable, the layer of water above the fires is fairly thin, and the highest efficient heating surface is comparatively small. Yet the evaporating effect of a Lancashire boiler is equivalent to that of a water-tube boiler per pound of fuel. This result is probably due mainly to the ease with which the steam can be set free from the water, the heating surface is never dry, and the fact that the fire is water-jacketed; and not because the Lancashire boiler has any superiority in circulation, for after steam is formed, even when the boiler has cross-tubes, the circulation below the firebox-level is negligible. The same action goes on as in a tube: a bubble of steam, once evolved, is in a hurry to join the other free steam and rushes to the surface, not lending the heavy water any assistance to rise, but rather treading it down to the best of its ability. In this way, the upper half of the furnace-tubes have steam rising from them, while the water surrounding the lower half is dead. This is demonstrated by the greater accumulation of scale, as well as its character, upon the upper half; and when corrosion, from bad water, takes place, evidences of it will be first found at and below the level of the fire-bars, while often the upper surfaces of the furnace and of the shell are perfectly sound: the dead-water at the bottom becoming denser and fuller of impurities every hour.

Bad circulation also adds to the stresses and strains to which a cylindrical boiler is subjected, as the temperatures vary greatly

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in different parts.* These unequal strains are, indeed, responsible for nearly all the troubles of leaky seams, grooving, etc., common to cylindrical boilers.

The movements on the water-surface of a Lancashire boiler are from front to back, added to a cross action either from both sides to the centre, or from the middle outwards to the sides. The greatest disturbance and most rapid formation of steam occur over the fires, and just near the bridge; beyond the bridge the temperature rapidly falls, and less steam is generated. It is doubtful, after a layer of soot is deposited, whether much steam is formed at the sides of shell, and the bottom-flue may even steal some heat from the boiler, if the gases are allowed to become too cool: that is, the temperature becomes insufficient to overcome the insulation due to the boiler-plate *plus* the steam-temperature. Consequently, with rising pressures, there should be a corresponding rise in the flue-temperature.

Numerous attempts have been made to induce circulation in cylindrical boilers. Various kinds of baffles have been used, but they failed, because, as already shewn, the warm convection-currents obstinately refused to move downward into the colder zones. Various kinds of hoods, cones and cross-tubes (large and small, and round and straight) have also been tried; but they failed, because the column of water in them does not remain solid after steam begins to form. They then act very much like the bottom tube in a forced-draught water-tube boiler, being filled with rapidly-generated steam and blowing out the water. The steam in contact with the fire is then a source of loss rather than of gain, as it does not extract so much heat from the fire as water. They all fail as water-circulators so soon as the column of water is broken by steam, even if, before that time, they have been effectual. The general result of their use is destruction of the cross-tubes, and a lowering of the boiler-efficiency.

It is very difficult to illustrate this action in the model, but the following experiment will show the writer's meaning. In the glass tube, *a* (Fig. 4, Plate XXIV.), the rise of steam-bubbles is visible, and illustrates the formation of steam above the heat-

* *Manchester Steam Users' Association: Report on a Series of Red-hot Furnace Crown Experiments, to ascertain the Result of Injecting the Feed-water into a Boiler when short of Water and with Fires burning*, by the Chief Engineer, Mr. Lavington E. Fletcher, 1890, pages 48 to 50.

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ing line (in this case, the gas-ring, *c*), for instance, the fire-bar level in a cylindrical boiler. Below the fire-level, there is not a deep disturbance, and the heat is only carried downward by the sides of the vessel.

Mechanical circulators of the water have been used. Mr. H. W. Harman, in 1859, used a screw-propeller, working at the bottom and back-end of the boiler, and actuated by a spindle passing through the boiler-shell at the top.*

Recognizing the difficulties of maintaining a solid column of circulating water and the importance of keeping the boiler-water in motion, the writer has introduced the Hotchkiss automatic circulator, which deals with the water only (see Appendix). It avails itself of the convection-currents induced when the boiler-fire is lighted, and the movement of the water is maintained with a very slight loss of heat by radiation. It takes the hottest water from over the furnaces and delivers it along the bottom of the boiler. In this manner, the heat is more evenly distributed and the lower layers of water are kept in motion, compelling a general movement of water all over the boiler. There does not appear to be any fear of over-circulation by this type of apparatus, because solid water alone is moved, and this compels a large body of water to continually brush over the heating surface. With this apparatus, cylindrical boilers can be pushed without fear, and kept standing under large fires without inducing undue stresses. This is due to the temperature-equalizing tendency of this kind of circulation, resulting in an almost equal expansion of the top and of the bottom of the boiler. As convection-currents are the primary movers, it is not surprising to learn that this circulator starts automatically, and maintains the flow continuously until the boiler returns to the temperature of the surrounding air. Hence, when the fires are banked, there is still a distribution of heat going on from the top to the bottom, and whether the boiler is working or standing, lighting up or cooling down, there is a constant interchange of water from above to below the furnaces.

Probably, few boiler-owners consider the extremes of temperature to which a boiler is subjected. The temperature of the fire ordinarily averages 2,500° Fahr. to 3,000° Fahr. Sometimes, the last flue has a temperature between 300° and 400° Fahr., a

* British patent, 1859, No. 1909.

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fall of 2,200° to 2,600°. The inside temperature of the boiler, being that of the steam, is anywhere between 212° and 400° Fahr., there is thus a great strain through differing heats on the two skins of the boiler-plate; and, while the heat has a free passage and is not stored in the plate itself, no harm is done. Knowing the great difference between the temperature of the fire and of the gases in the last flues, it is not surprising to learn that the circulation at the bottom of a Lancashire or Cornish boiler is either very dull or non-existing, the heat in the flue being barely sufficient to maintain the water at steaming temperature, much less make steam; and great differences of temperature will also occur between the layers of water at the top and the bottom of the boiler.

In a marine boiler, the difference between the temperatures of the top and the bottom of the boiler is very marked, as there are no under-flues. Hydrokineters and donkey-pumps are requisitioned, when lighting up this type of boiler, both of these appliances requiring steam to operate them; while the Hotchkiss circulator does the work automatically and independently of the supply of steam from another boiler. Such considerable contrasts of temperature occurring in a boiler induce great strains in certain parts, and these exhibit themselves often in a very unaccountable manner.

Although the circulation of the water in the top drums of water-tube boilers cannot assist in increasing the output of steam, as there is practically no fire-surface, yet there are other considerations in tubular boilers, which tend to become of greater importance, such as the deposition of scale, grease in the feed-water, freedom from mud, etc. Whether scale, $\frac{1}{4}$ inch thick, decreases the efficiency of the heating surfaces by 25 per cent., the writer cannot say, but it is clear that if the thickness of the plate be increased, a greater head of heat must be maintained outside, so as to deliver the same bulk of heat to the water per hour through the greater thickness of plate; and, therefore, it is of great importance that the inside as well as the outside surfaces should be kept clean. The writer may point out that the Hotchkiss automatic circulator, while doing its work as a circulator, collects and removes the suspended solids almost as soon as formed, maintaining a clean surface of the water for the freest possible discharge of steam, preventing priming, and removing

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suspended solids, so that the steaming temperature is kept as low as possible.

But the other boiler trouble, oil and grease, is more dangerous and an enemy to be far more feared than scale. Steam can be made with scale, $\frac{1}{2}$ inch thick, on the furnace-flue, but pasty grease, $\frac{1}{16}$ inch and often $\frac{1}{32}$ inch thick, is sufficient to burn any furnace-crown to bursting point.* This danger is greatly minimized, and in most cases completely removed, by the collecting power of the Hotchkiss automatic circulator: it only requires that the oil or the grease should separate and float, then arrange the funnel or funnels to suit the flow, and all danger is removed. Many of the best oils, when the water is very pure, tend to keep in emulsion, even in the boiler: this may require special treatment to induce separation, and then the Hotchkiss automatic separator will remove it. The writer would suggest to those troubled with grease in their boilers that, when a boiler is stopped for cleaning, the surface-water should be blown off from a cock on the boiler-front, say, 6 inches below the water-level, so that the oily skin or scum will be run off and will not shroud the furnace-tube and boiler-shell as it descends.

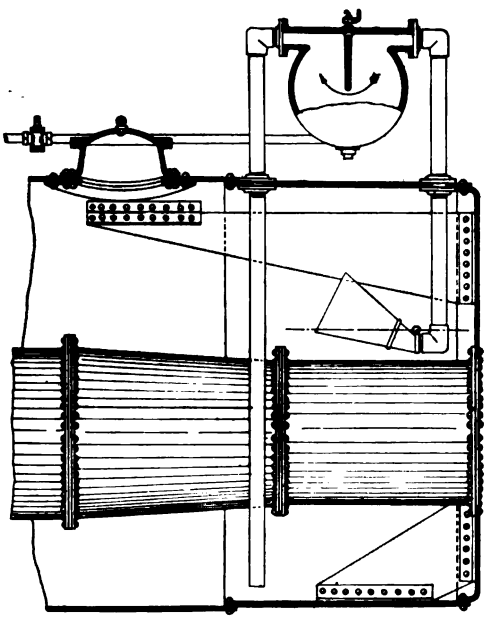

FIG. 8.—CIRCULATOR FIXED ON A LANCASHIRE BOILER.

* "Some Experiments on the Transmission of Heat through Tube-plates," by Mr. A. J. Durston, *Transactions of the Institution of Naval Architects*, 1893, vol. xxxiv., pages 133 and 134.

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APPENDIX.—Hotchkiss Automatic Circulator.

Fig. 8 shows a small-sized Hotchkiss automatic circulator fitted on the centre-line of a Lancashire boiler. It consists mainly of a reservoir, a funnel and three pipes.

The funnel is fitted inside the boiler, with the edge just below the lowest working water-level, thus allowing for plenty of fluctuation of level. It is placed as nearly as possible at the back end of the boiler, with the mouth pointing to the furnace-front, and is connected to the reservoir by the pipe passing through the boiler-shell.

The reservoir is a sphere, having three holes at the top, for the inlet-pipe, the outflow-pipe and the air-relief cock; and a blow-off pipe at the bottom. Internally, a diaphragm extends right across, and half way down the reservoir; and this gives the current, from the inlet to the outlet, a longer path and tends to add a downward motion to the deposit. At the bottom of the reservoir, a blow-off pipe is fitted; it is carried to the most convenient place for the stokers' use (generally the stoke-hole), and is provided with a blow-off cock under easy control.

By filling the reservoir and pipes with water before lighting the boiler-fires, circulation commences upwards by the funnel-pipe and downwards by the return-pipe, within a short time of lighting the fires, and never ceases until the boiler is as cold as the surrounding atmosphere.

By this appliance, floating particles of lime, mud, grease or oil, carried upward, by the ebullition, to the water-surface, are caught by the funnel and lifted into the reservoir, where they are deposited in the quieter water and can be blown out from time to time. For the removal of oil in a fluid condition or very light particles of deposit, a second blow-off pipe is fitted in place of the air-relief cock, but in the writer's experience most of the grease is absorbed by the lime-deposits, and removed at the bottom blow-off pipe.

The circulation, having once been set up, rapidly increases in speed, and attains its maximum rate before any steam is formed, taking the hot water from over the furnace-tubes, and discharging it along the bottom of the boiler, where the temperature is lowest. It circulates water only, and steam should never be formed in the connections. The circulation is set up automatically through the difference in temperature between the top and the bottom layers of the water in the boiler; and, having once started, the addition of heat merely increases the speed. Its object is mainly to distribute more equally the heat all over the boiler; and, as the circulation never stops, this diffusion of the heat continues, whether the boiler is lighting up, working, standing under banked fires, or cooling down.

The circulation is its most important function, but, the other operations are also important, such as removing suspended solids, grease and oil, so that the steaming surface is kept clean; and, priming is practically impossible if a proper working level be maintained. The removal of the solids from the water also tends to keep down the boiling-point, so that steam is raised much more easily than would otherwise be the case.

Numerous tests have shewn that economies varying from 3 to 18 per cent. have been made in the coal-consumption, entirely due to the better circulation of the water. Table I. records the results of experiments conducted under the ordinary conditions of working, the same grade of fuel being used in each experiment, and all other things being equal.

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TABLE I.—EXPERIMENTS ON FIVE LANCASHIRE BOILERS, 30 FEET LONG AND 8 FEET IN DIAMETER, FITTED WITH MELDRUM FURNACES, AT HAYDOCK COLLIERIES, ST. HELENS.

Experiment.		I. Without Hotchkiss Separator.	II. With Hotchkiss Separator.
Duration of test, ...	hours	310·500	310·000
Water evaporated, ...	pounds	5,222,093·000	5,417,613·000
Coal consumed, ...	,,	852,768·000	856,016·000
Ash, ...	,,	107,856·000	114,912·000
Average temperature of feed-water,	degs. Fahr.	146·870	132·770
Average boiler-pressure per square inch,	pounds	83·010	85·440
Water evaporated per pound of coal,	,,	6·123	6·328
Water evaporated per pound of combustible,	pounds	7·010	7·310
Ash in coal, ...	per cent.	12·640	13·420
Total water evaporated from and at 212° Fahr.,	pounds	5,766,757·290	6,065,017·750
Water evaporated per pound of coal from and at 212° Fahr., ...	pounds	6·762	7·085
Water evaporated per pound of combustible from and at 212° Fahr., ...	pounds	7·741	8·183

The increased evaporation per pound of combustible from and at 212° Fahr. was 5·710 per cent. The average coal-consumption was 22,214,192 pounds per annum, and a saving of 5·710 per cent. is 566·26 tons. In most instances, doubtless, the removal of solids and grease has also tended to increase the economies.

The PRESIDENT (Mr. John Gerrard) moved a vote of thanks to Mr. Ross for his most perfect illustrations of water-circulation in steam-boilers. The question had been clearly demonstrated by means of the practical examples shown by Mr. Ross.

Mr. JOSEPH DICKINSON said that he had much pleasure in seconding the proposition.

The motion was cordially adopted.

Mr. A. Ross, in acknowledging the vote, said that it had been a pleasure to him to read the paper and to illustrate it with experiments and lantern-views. The priming of boilers was due either to an accumulation of grease or of scum on the surface of the water. The freer the disengagement of the steam from the water, the better the effect, and anything that retarded the discharge of the steam would diminish the efficiency of the boiler.

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MANCHESTER GEOLOGICAL AND MINING SOCIETY.

ORDINARY MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
MAY 9TH, 1905.

MR. JOHN GERRARD, PRESIDENT, IN THE CHAIR

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. ARTHUR ROSS, Colliery Manager, Moston Colliery, Newton Heath, Manchester.

Mr. JOHN SMITH, Colliery Manager, Bower Colliery, Hollinwood, near Oldham.

Mr. FREDERICK SPEAKMAN, Mining Engineer, Church Street, Leigh, Lancashire.

Mr. JAMES E. STEWART, Assistant Manager, Pekin Syndicate's Collieries, North China.

Mr. CHARLES STANLEY WHITWORTH, Assistant Colliery Manager, 24, Montgomery Street, Hollinwood, near Oldham.

ASSOCIATE MEMBER—

Mr. SAMUEL CAMPBELL PRESTON, Close House, St. Helen's, Lancashire.

ASSOCIATE—

Mr. WILLIAM WOODWARD, Assistant Engineer, Lancashire Electric Power Company, 196, Deansgate, Manchester.

Mr. WALTER BALDWIN read the following paper on "*Prestwichia anthrax* and *Belinurus lunatus* from Sparth Bottoms, Rochdale":—

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PRESTWICHIA ANTHRAX AND *BELINURUS LUNATUS* FROM SPARTH BOTTOMS, ROCHDALE.

By WALTER BALDWIN.

I. Introduction.—The writer has again pleasure in recording further examples of Arthropoda from the Middle Coal-measure rocks exposed to view at Sparth Bottoms, in the neighbourhood of Rochdale.

The members, who visited this locality last year, will be sufficiently familiar with the ground to recognize that there are at least three horizons on which the remains of fossil Arthropoda occur. The lowest of these has furnished the individuals forming the title of this paper, and has been termed in previous papers* "the *Carbonicola*-bed," on account of the great number of specimens of that genus found in it, which first led to its discovery. The bed lies about 135 feet above the Royley coal-seam.

II. Prestwichia anthrax (Fig. 1).—This is the first recorded example of this species from the Lancashire coal-field and is, on that account, of great interest. Unfortunately, the animal is only represented by the cephalic shield and this is not entire, owing to the absence of the right genal spine, whilst the left is buried in the matrix. This gives the animal a deceptive appearance, as the curious lateral extension, which distinguishes it from all the other king-crabs, is wanting. The frontal doublure is strongly marked. The central portion (the glabella) is prominent and declines towards the circumference: it occupies about two-thirds of the whole depth of the cephalon and is strongly marked by a double arched front as in the Belinuri. The larval

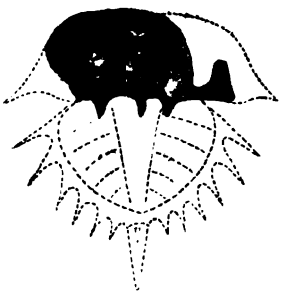

FIG. 1. *PRESTWICHIA ANTHRAX*. THE RESTORED PORTION IS SHEWN IN DOTTED LINES. FULL SIZE.

* "*Bellinurus bellulus*, from Sparth, Rochdale," by Mr. Walter Baldwin, *Transactions of the Manchester Geological and Mining Society*, 1903, vol. xxviii., page 198; and "*Eoscorpius Sparthensis*, sp. nov., from the Middle Coal-measures of Lancashire," by Messrs. Walter Baldwin and William Henry Sutcliffe, *Quarterly Journal of the Geological Society of London*, 1904, vol. lx., page 394.

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eye-spots (two in number) appear on the anterior border of the glabella. The median and lateral ridges of the glabella are continued backward beyond the posterior border of the cephalic shield, forming thereby three prominent spines. These cheek-spines are similar to those on Prof. Joseph Prestwich's specimen,* but are more pronounced and farther apart: they differ from Fig. 6*a* of the same work, as the lateral spines are parallel to the axis.

The following measurements are taken from the Sparth specimen:—Greatest breadth of head-shield preserved, 25 millimetres; greatest length of head-shield preserved, 12 millimetres; greatest breadth of glabella, 9 millimetres; greatest length of glabella, 8 millimetres; greatest length of spines from posterior border of cephalon, 3 millimetres.

This specimen was discovered by Mr. W. A. Parker in 1904, and a further example, but more fragmentary, has been recently found by the writer, on the same horizon.

III. History of Prestwichia anthrax.—Prestwichia anthrax was first discovered in the Pennystone ironstone-band of the Coal-measures at Coalbrookdale, Shropshire, and was figured and described in 1834-1836 by the late Sir Joseph Prestwich as *Limulus anthrax* in his important memoir "On the Geology of Coalbrook Dale."† In 1863, Mr. William Hellier Baily classed it among the Belinuri as *Bellinurus anthrax*.‡ Four years later, Dr. Henry Woodward figured and described it as *Prestwichia anthrax* in his paper "On some Points in the Structure of the Xiphosura, having Reference to their Relationship with the Eurypteridæ,"§ and this name is now universally accepted.

IV. Bibliography of Prestwichia anthrax.—

"Remarks on some Coal-measure Crustacea belonging to the Genus *Belinurus*, König; with Description of two new Species from Queen's County, Ireland," by Mr. William Hellier Baily, *Annals and Magazine of Natural History*, third series, 1863, vol. xi., page 107.

"On the Geology of Coalbrook Dale," by Mr. Joseph Prestwich, Jun., *Transactions of the Geological Society of London*, second series, 1840, vol. v., page 413.

* *A Monograph of the British Fossil Crustacea, belonging to the Order Merostomata*, by Dr. Henry Woodward, Part V., page 244 and Plate XXXI., Fig. 6, Palæontographical Society, 1878, vol. xxxii.

† *Transactions of the Geological Society of London*, second series, 1840, vol. v., page 491.

‡ *Annals and Magazine of Natural History*, third series, 1863, vol. xi., page 113.

§ *Quarterly Journal of the Geological Society of London*, 1867, vol. xxiii., page 32.

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"On some Points in the Structure of the Xiphosura, having Reference to their Relationship with the Eurypteridæ," by Dr. Henry Woodward, *Quarterly Journal of the Geological Society of London*, 1867, vol. xxiii., page 28.

A Monograph of the British Fossil Crustacea, belonging to the Order Merostomata, by Dr. Henry Woodward, Part V., Palæontographical Society, 1878, vol. xxxii.

V. Belinurus lunatus (*olim B. bellulus*).—For this species, the writer has, after some consideration, adopted the term *lunatus* as being the most descriptive. A short time ago, Dr. F. A. Bather suggested this name to the writer, his reason being that it had been termed *Monoculus lunatus* by Mr. William Martin in 1809,* whereas Mr. Charles König figured it as *Belinurus bellulus* in 1825.† It is certainly not a *Monoculus*, and as Mr. William Martin's names are universally accepted, *Belinurus lunatus* appears to be the most correct.

Previous to the discovery of the present specimen (Fig. 2), the writer had described a head-shield of *Belinurus* from the same horizon at Sparth.

The present one, however, possesses points which are worthy of description. The head-shield is somewhat crushed, and demands no special attention. The thoracic segments, five in number, are strongly trilobed, and possess a narrow central axis with the median portion of each somite marked by a single tubercle. The lateral extremity of each segment is produced, so as to form an acutely pointed and recurved spine: they are lanceolate in form, and differ somewhat from the examples figured in Dr. Henry Woodward's *Monograph of the British Fossil Crustacea belonging to the Order Merostomata*, having much broader bases.‡ The thoracic segments are considered by Dr. Woodward to have been capable of flexure, thus forming a distinctive feature as compared with *Prestwichia* in which they are anchylosed. The abdomen is trilobed and also

FIG. 2.—*BELINURUS LUNATUS*. THE RESTORED PORTION IS SHEWN IN DOTTED LINES. FULL SIZE.

* *Petrificata Derbiensia; or, Figures and Descriptions of Petrifactions collected in Derbyshire*, by Mr. William Martin, 1809, Plate 45, Fig. 4.

† *Icones fossiles sectiles*, by Mr. C. König, 1825, Plate XVIII., Fig. 230.

‡ Part V., page 239 and Plate XXXI., Figs. 3*a* and 3*b*, Palæontographical Society, 1878, vol. xxxii.

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possesses a central axis, which is not divided into somites, and bears a large tubercle anterior to the point of insertion of the telson. The lateral somites of the abdominal segments are marked by sutures, and terminate laterally in spines similar to those of the thoracic segments. The telson has a well-marked central ridge, and (though not entire) appears to have been not quite so long as the rest of the animal.

The following measurements are taken from the fossil:—Total estimated length, 37 millimetres; greatest length of head-shield preserved, 8 millimetres; greatest breadth of head-shield preserved, 21 millimetres; greatest length of glabella, 8 millimetres; greatest length of thorax, 7 millimetres; greatest breadth of thorax, exclusive of spines, 16 millimetres; greatest length of abdomen, 2·5 millimetres; greatest breadth of abdomen, exclusive of spines, 9 millimetres; greatest length of thoracic spines, 2 millimetres; greatest length of telson preserved, 9 millimetres; and greatest width of telson, 2 millimetres.

This *Belinurus* was discovered by Mr. W. H. Sutcliffe, and with the *Prestwichia anthrax* is in the collection of Messrs. W. H. Sutcliffe, W. A. Parker and the writer.

VI. Bibliography of Belinurus bellulus.—

"*Bellinurus bellulus*, from Sparth, Rochdale," by Mr. Walter Baldwin, *Transactions of the Manchester Geological and Mining Society*, 1903, vol. xxviii., page 19·.

"The Palæontology of the Lancashire Coal-measures," Part II., by Mr. H. Bolton, *Transactions of the Manchester Geological and Mining Society*, 1904, vol. xxviii., page 578.

"Notes on some Fossil Crustacea, and a Chilognathous Myriapod, from the Coal-measures of the West of Scotland," by Dr. Henry Woodward, *Transactions of the Geological Society of Glasgow*, 1866, vol. ii., page 234.

Prof. W. BOYD DAWKINS said that he had great pleasure in moving a vote of thanks to Mr. Baldwin for his paper. By his work at Sparth Bottoms, Mr. Baldwin was doing admirable service in the general interest of geology and of this society, and he was one of an ardent band of explorers, which included Mr. Sutcliffe and Mr. Parker.

Mr. W. SAINT seconded the motion, which was cordially adopted.

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The PRESIDENT (Mr. John Gerrard) asked whether nodules containing similar specimens had been found over the Arley mine in other parts of Lancashire.

Mr. W. BALDWIN replied that this was the only horizon in the district at which he had worked and found them, but he believed that *Belinurus lunatus* had also been found in the Oldham district.

The PRESIDENT (Mr. John Gerrard) remarked that the fact of Sparth Bottoms being an open quarry facilitated research.

Prof. W. BOYD DAWKINS said that there was a layer above the Five-Quarters mine exposed in the section near Clifton, on the banks of the river Irwell, where there was a large number of nodules containing similar remains. He had also obtained some from other localities.

Mr. W. BALDWIN said that some very important specimens were still being found in the same locality.

DISCUSSION ON THE CAPPING OF WIRE-ROPES.*

The PRESIDENT (Mr. John Gerrard) said that his attention was called to this question by several breakages of ropes within caps in actual winding. In a number of cases, the break occurred at the base of the cap, where the wires were turned back to form the bulge to be gripped by the cap. These caps were of three forms: (1) The common one, where the rope was opened and the wires turned back on the rope, enclosed within a cap held by several hoops; (2) one in which the wires of the rope were turned back over tongues or cones of metal, the cap again being held by several hoops; and (3) another form, in which the turned-back wires were combined into a solid cap or socket of white metal. All of these had failed in actual use. When caps were made on similar lines, and submitted to measured tests, at the Sheffield, Birkenhead or Dudley testing-works, it was proved that these caps only gave from 40 to 60 per cent. of the breaking-strain of the ropes. To his mind, this was far from satisfactory. Mr. W. C. Blackett,† in 1901, submitted a cap in

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 604.

† "A Method of Socketing a Winding-rope, etc.," *Ibid.*, 1901, vol. xxiii., page 10.

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which the wires were not turned back: they were spread out straight within a solid socket or cap, and white metal was run so as to form a solid cone; and with this cap Mr. Blackett obtained, under tests, 80 per cent. of the breaking-strain of the rope. In Lancashire, at Ladyshore colliery, Mr. Herbert Fletcher introduced a somewhat similar cap 28 years ago, and this had continued in use up to the present time at three shafts. It had now been proved that by giving attention to the composition of the white metal, using lead, 60 per cent.; tin, 30 per cent.; antimony, 9 per cent.; and bismuth, 1 per cent.; also by well cleaning the wires with paraffin, and by using resin-dust amongst the wires before running in the white metal, a capping could be made stronger than the rope.

Mr. F. L. Ward said that, in consequence of a winding-rope breaking at Bradford colliery, it was considered advisable to investigate the question of the efficiency of the system of capping. The rope broke inside the capel at the turned-back wires or bow, although it had only been at work a little over half the usual time of similar ropes, and subsequent tests of the broken wires revealed no undue weakness or deterioration.

The system of capping that had been in use for over 20 years without previously giving any cause for doubt was the usual type of hooped capel, having a total length of about 36 inches. The rope was wrapped tightly with soft iron-wire for the whole length of the capel, leaving the ends of the rope-wires projecting for turning back. Several extra layers of soft iron-wire were put on at the end, to form a cushion for the turning back of the wires which varied from 4 to 14 inches in length, so as to form a cone, when put on the soft iron-wire preparation. The whole was then tightly wrapped with soft iron-wire, and the capel (heated at the bottom of the eye) closed on to this cone. Three hoops, previously threaded on to the rope, were brought on to the capel and driven down until quite tight.

It was decided to have some capped ropes tested, and although confidence in the system of capping was not materially lessened by the breakage mentioned, the results of the tests were startling. (1) The first sample, being a piece taken from the winding-drum end of a disused improved patent steel rope, $3\frac{3}{4}$ inches in circumference, was capped in the usual manner. On the testing-

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machine, it commenced to draw out of the capel with only 12 tons of load, and continued to move until a load of 28·35 tons was reached, when it broke and came completely out. On investigation, it was found that the rope had broken at the inside of the turned-back wires, or in exactly the same way as the breakage already referred to. (2) The second sample was a capel, 24 inches in length over all, with three hoops, and the same preparation as the first sample, excepting that, being shorter, the length of the cone was reduced and consequently sharper. This test gave better results, and stood a load of 32·2 tons before breaking and drawing out. The breakage was exactly in the same place as in the first sample, that is, at the turn-back of the wires. (3) The same capel was again prepared, but, instead of wrapping it with soft iron-wire, tarred string was used. The load reached on testing was 26·68 tons, when the turned-back wires drew out without breaking.

Attention was then given to the question of socketing the end of the rope by running in white metal to form a cone. It was observed at the testing-works of the Sheffield Testing-works, Limited, who carried out all the tests, that, in order to ensure a firm hold by the testing-machine of the opposite end of the rope to the capping a metal-cone was formed, and this was stated to have been the practice for a great many years. Forged-steel sockets were procured, bored to form a cone, 8 inches long with a taper of 1 inch, that is, 1 inch larger in diameter at the bottom-end than at the top-end. For attaching to the cage, two ears, bored to receive a steel pin or bolt, project below the cone. (1) In the first test of a metal-cone, the socket was threaded on, and the rope wrapped for about 2 inches with soft iron-wire immediately above the position of the socket. The wires were opened out, without interfering with the twist of the rope, and the ends turned back (inwards) about $\frac{3}{4}$ inch. The socket was then drawn down to cover the end of the rope, and without any preparation of the wires by cleaning, white metal composed of magnolia-metal, with a little lead added to soften it, was poured in. On testing, the rope broke outside the socket under a load of 43·8 tons. The movement of the cone inside the socket during the test was very small, and only reached 0·20 inch at 40 tons. (2) For the second test, the preparation was similar to the last, excepting that the ends of the wires were straight, and not turned back. The result

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was that some of the wires drew out of the metal under a strain of 32·35 tons, indicating that the turned ends of the wire have an effect in resisting the strain. It was noticed that the wires drawn out had not separately been in contact with the white metal, but that there were several lying together.

Three further tests were subsequently made, the wires being straightened and the twist taken out, one having the ends turned back and the other two with straight projecting ends. After opening out the wires, they were washed in petroleum to remove all grease, and afterwards wiped and held over a red-coke fire. Powdered resin was then sprinkled on, and after the socket was placed in position, a further quantity was blown in amongst the wires by means of a small tube. The mixture of metal used was 70 per cent. of magnolia-metal and 30 per cent. of pure tin. The magnolia-metal was melted and the tin put into it, and immediately this was molten the mixture was poured into the sockets, so that any possibility of pouring on to the rope a metal of very high temperature was avoided. On testing, all the ropes broke some distance from the sockets at a load of 42½ tons. As two of the three test-pieces had not the ends of the wires turned back, proof was given that the metal adhered to the wires. The movement of the cones in the sockets during the tests varied from 0·02 inch to 0·11 inch at a strain of 35 tons.

A test was also made of a locked-coil rope, 1 inch in diameter, the rope breaking outside the socket with a load of 37·97 tons and a movement of 0·40 inch at a strain of 35 tons.

In practice, the socket is warmed before the metal is poured in, to such an extent that the hand cannot be held on it. After the socketing is completed it is allowed to cool before any load is applied.

Metal-filled sockets are now in use at the colliery, and, so far, have not given any cause for doubting their efficiency.

Referring to the temperature of the white metal and the possibility of altering the temper of the steel-wires of the rope by pouring into the socket, Mr. N. K. Turnbull, general manager for Messrs. Richard Johnson & Nephew, Limited, wire-drawers, stated that up to 900° Fahr., steel-wire will not be affected, if not hammered or in any way worked. This temperature is about the average one used in galvanizing steel-wires, without materially altering their tensile strength.

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Mr. J. WHITTAKER said that he had used locked-coil winding-ropes for about 16 years. A solid cone cap was used and formerly the wires were bent back to form a sort of cone, which was drawn into the cap, and the cavity filled up with a mixture of equal parts of lead and tin. In recapping, a few of the wires were sometimes found broken at the bend. One winding-rope had entirely broken in the cap. It was of improved plough steel, 4 inches in circumference, having a breaking strength of about 90 tons and a load of 7½ tons. The rope had only been at work for about 7 months. The wires were bent back as usual in capping and filled up with lead and tin. All the wires broke at the bend and the rope drew out of the cap, leaving the broken wires embedded in the white metal. Probably, the steel was too hard to bear the bending without injury. The wires were now only opened out like a brush and not bent back, and the cavity was filled with lead and tin as before. Various tests shewed that when the wires were bent back in the cap, they broke at about 55 per cent. of the ultimate strength of the rope, and when they were opened out only and not bent back they broke at about 80 per cent. of the ultimate strength.

Mr. JOSEPH DICKINSON stated that, in most of the cappings exhibited, the rope was verging on a very sharp edge. Now, in the ordinary winding of collieries, the rope and the cap seldom keep perfectly straight at the bottom: they are there a little slack. It would be better to take the edge off, thus forming a little bell-mouth.

Mr. F. L. WARD said that the rope at the Bradford collieries was covered with white metal to the limit of the capping, which ended with a small bell-mouth.

The PRESIDENT (Mr. John Gerrard) said that one of the advantages of having the cap made of molten metal was the exclusion of water and, with it, the risk of corrosion. In the old form, rust was found, but it could not possibly accumulate in the new form of cap. He (Mr. Gerrard) objected to Mr. Whittaker's form of cap, because it embodied the old principle of capping, that was, by turning back the wires of the rope, and bending was the first step to breaking anything. In this way, the pernicious, unscientific and absolutely objectionable form of capping by bending back the wires was continued.

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Mr. Peter Thompson said that at the Chamber collieries, with which he was connected, after some disappointment he resolved to put ferrules on the end of the ropes and weld them together, as shown in the model exhibited. The result had been quite successful, and there was no danger of slipping.

Mr. William Saint said that, when visiting the United States of America in the early eighties, he noticed that colliery winding-ropes were capped with conical capels, which were secured by means of white-metal filling. This method was considered to be safer in use, and more expeditious to make, than the ordinary form of capping used in this country. The only case of failure of a solid capped rope of which he knew was one in which the rope had been bound at the neck of the cap with copper-wire; and the fracture occurred at the neck of the cap. At first it was supposed that the temper of the wires had been affected by the molten metal when the capping was made; but, on separating and testing the embedded wires, they were found to be as good as when they were new. It was supposed that in some way galvanic action had been set up between the copper- and steel-wires where they were bound together, and had thus diminished the strength of the rope.

The further discussion was adjourned.

Prof. W. Boyd Dawkins read the following "Note on the Discovery of the South-eastern Coal-field":—

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NOTE ON THE DISCOVERY OF THE SOUTH-EASTERN COAL-FIELD.

By Professor W. BOYD DAWKINS, D.Sc., F.R.S.

It will be within the recollection of many of the members of the Manchester Geological and Mining Society that in 1897 the question of the discovery of the south-eastern coal-field was fully discussed* and the relative share of Mr. Brady, Sir Edward Watkin, myself and others fully set out and proved by the original documents, and by the publications. Prof. Hull, in the last edition of the *Coal-fields of Great Britain*, revives the question in such a way that I feel it my duty, in the interest of fairness and truth, to bring the matter again before the Society.

"The credit," he writes, "of experimentally demonstrating the existence of coal-seams below the chalk is due to Mr. Francis Brady, engineer of the Channel tunnel, under the advice of Prof. Boyd Dawkins, F.R.S., and an experimental boring was commenced in a position at the foot of Shakespeare Cliff, near Dover, in 1895-6."

It would be difficult to compress more errors into one sentence than are in the above quotation. The only statement which is true relates to the place of the boring. The credit of experimentally proving the existence of the coal-field is due to Sir Edward Watkin, chairman both of the South-eastern Railway and of the Channel Tunnel Company, who acted under my advice and sent on to me all reports connected with the boring. Mr. Brady was engineer in charge of the bore-hole and acted under Sir Edward Watkin's instructions. I never had occasion to advise Mr. Brady. Nor was the boring "commenced in 1895-6." It was begun in 1886 and, from that time down to the discovery of the Coal-measures in 1890, the work of identifying the specimens and fixing the horizons of the strata penetrated in the bore-hole—or, in other words, all the geology—fell to me. The last of a long series of reports to Sir Edward Watkin is dated 8th July, 1891.

* *Trans. Manch. Geol. Society*, vol. xxv., part vi., February 9th, 1897.

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All this is ancient history. The progress of the boring was recorded by me, from time to time, in the *Reports* of the British Association (1887, 1890, 1899) and in the publications of the Royal Institution (6th June, 1890) and the Manchester Geological Society (1890, 1893, 1894, 1897). They were also communicated to the public at large in the *Contemporary Review* (April, 1890), in *Nature* (6th March, 1890), the *Colliery Guardian*, and the *Iron and Coal Trades Review*.

In 1897, after a full debate, Sir Edward Watkin's claim was amply vindicated before this Society. Still later the history of the discovery was dealt with in my statement on the "Buried Coal-fields of Southern England," prepared at the request of the Royal Commission on Coal Supplies in 1903 (*Final Report*, part x., p. 28).

It is not, therefore, from lack of sources of information that Prof. Hull has written the above paragraph in a work which professes to give the last word on British coal-fields. The paragraph is obviously written in ignorance of the facts of the discovery. It is unjust to the memory of Sir Edward Watkin, who proved, by practical experiment, the truth of Godwin Austen's view as to the eastward range of the Coal-measures of Somerset under the secondary rocks. His boring at the Shakespeare Cliff proved the presence of coal in Kent. It has formed a starting point for other similar borings that will ultimately define the range of the coal-field and that may bring about economic changes in south-eastern England similar to those brought about by borings in northern France and Belgium.

I have felt some diffidence in bringing the matter before the Society, but the publication of the paragraph referred to in the last edition of Prof. Hull's work left me no alternative but to make a few observations thereon by way of correction.

It had been very unpleasant to me to make anything of the nature of a personal statement before this or any other Society. I am impelled to make it, because if I am silent that paragraph will pass current in general literature and Sir Edward Watkin's memory will not be vindicated.

Mr. Joseph Dickinson moved a vote of thanks to Prof. Boyd Dawkins for bringing the subject before the Society, and said that he thought Prof. Hull would be very pleased to have

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the matter set right. It is a mistake like that which was made by Mr. N. Griffith when he brought the subject before the North of England Institute of Mining Engineers at their Wigan meeting, in the year 1896. He (Mr. Dickinson) happened to be present at the time and mentioned pretty much the same thing that Prof. Boyd Dawkins had stated. In writing a large book like that of Prof. Hull's a person was very apt to make a slip.

The motion having been seconded, was cordially adopted.

Mr. Henry Hall, I.S.O., said that he always connected the name of Prof. Boyd Dawkins with the operations going on at Dover, and he believed it was that gentleman who had brought the whole subject within the range of practical politics and that otherwise, at any rate as yet, there would have been no sinkings at Dover.

The President (Mr. Gerrard) said that he was precluded from making any remarks because of his close connection with the place and the people; the less he said the better. If he might ask Prof. Boyd Dawkins a question, he should like to know whether it was from personal examination of the borings that the publication of the section was made, and whether he vouched for the accuracy of the section

Mr. Joseph Dickinson, with reference to Mr. Hall's remarks, said he thought the matter would in time have come to a head as it had done. The plans and sections of Sir Joseph Prestwich lay down that the probable line of coal ran through the very spot where the bore-hole was put down, and while we were much indebted to Prof. Boyd Dawkins for what he had done in advising Sir Edward Watkin to make the boring, still we must not forget that Godwin Austen and Sir Joseph Prestwich, many years ago, threw the first light on the matter. The coal-field, as they have indicated, is part of the coal-field continuing from South Wales through Somerset and even across the English Channel into Belgium and as far as Warsaw in Poland.

Prof. Boyd Dawkins, in replying, said: The President has asked me whether I am responsible for the accuracy of the whole of that section. Well, now, that section is divided into two parts: first of all, that relating to the cretaceous and

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jurassic strata, which I identified by means of the fossils and through which the boring was made by the jumping process. When the Coal-measures were reached the diamond drill was used and perfect cores obtained. With this section I had comparatively little to do because the Coal-measure sandstones, shales, underclays and coals were matters of common knowledge. I have, however, examined many of the cores, and studied samples from most, if not all, of the coal-seams. The thickness of the sandstones and shales was clearly defined by the cores: that of the coals was arrived at by the sinking of the drill before other rocks were struck, because there were no perfect cores of coal. It is a matter of physical impossibility, as far as I know, to get a perfect cylinder of coal by the diamond drill, because the coal is largely ground to dust in the process of boring. Under these circumstances, it is impossible to ascertain with absolute accuracy the exact thickness of the seams. The figures are purely boring figures and only approximately accurate. As to the further question raised by Mr. Hall and Mr. Dickinson, I feel the credit of this exploration, of bringing it to an experiment, is undoubtedly Sir Edward Watkin's and none other. I certainly cannot aspire to take the high place which you have assigned to me, or anything beyond that of one who has been very fortunate in finding people to work with who would listen to what I had to say.

The whole question, there can be no doubt whatever, that the prime mover in all this matter was my old friend, Godwin Austen. His view with regard to the range of the Coal-measures has borne most wonderful fruit in Germany and Belgium. They have enlarged the range of the coal-field enormously towards the west, and there can be no moral doubt felt amongst the geologists of this country, after the Royal Commission of 1884, but that the area of Dover was an area in which the enterprise was likely to be crowned with success.

The PRESIDENT: My object in asking as to the accuracy of the boring was a purely practical one. The discovery of the Coal-measures is ancient history. What we want now is to discover a workable seam of coal, as the value of the discovery of Coal-measures in Kent depends upon there being workable seams of coal.

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MANCHESTER GEOLOGICAL AND MINING SOCIETY.

ORDINARY MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
JUNE 20TH, 1905.

MR. JOHN GERRARD, PRESIDENT, IN THE CHAIR.

The following gentleman was elected, having been previously nominated:—

ASSOCIATE MEMBER—
Mr. ARTHUR ROSS, 1 Glengall Road, Old Kent Road, London, E.C.

The PRESIDENT (Mr. John Gerrard) said that it was with great regret that he had to announce the deaths of Mr. George Peace and Mr. Thomas Banks. Both were Lancashire mining engineers of high repute, and both had long been connected with this Society. He begged to propose a silent vote of sympathy with the relatives of both gentlemen.

The vote was passed in silence, the members rising.

DISCUSSION ON THE CAPPING OF WIRE-ROPES.*

Mr. JOSEPH DICKINSON stated that none of the cappings produced showed a bell-mouth to prevent any cutting action, where the rope emerged from the cap; and he would be glad to hear some reference to this point, which he had mentioned when the subject was introduced at the previous meeting.

The PRESIDENT (Mr. John Gerrard) said that a new cap had been described, at a recent meeting of the South Wales Institute of Engineers, by Mr. W. H. Becker.† Mr. Becker had sent a

* *Trans. Inst. M. E.*, 1905, vol. xxix., pages 604 and 625.

† *Proceedings of the South Wales Institute of Engineers*, 1905, vol. xxiv., page 151.

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model of the capping, together with several pieces of rope which had been tested. This cap consisted of sliding interlocking wedges, of special construction, held together by a number of encircling hoops. The records of the tests were attached to each rope, showing the strain under which each broke, namely, 65 tons, 45 tons, 65 tons, 64½ tons, 42½ tons and 67½ tons. The notable points were that the inventor claimed to get 100 per cent. of efficiency in the caps, and that, in every case, the rope broke outside the cap.

Mr. William Pickup said that the point mentioned by Mr. Dickinson was an important one. His first experience of the use of solid caps was for haulage-purposes, and then he found that the wires of the rope were apt to break, just where they emerged from the cap. If the edge of the cap was slightly hollowed, as Mr. Dickinson recommended, it would, he thought, be an improvement, and might prevent the wires from breaking at that point.

His experience of winding-rope caps and their improvement began some years ago. At that time, at the colliery with which he was connected, a cap was used with rivets through it, between the collars. He did not like the rivets, feeling sure that they had a bad effect upon the rope, and he, therefore, arranged that the caps, as they were taken off, should be taken to pieces and examined. He found that a number of wires were broken, in all cases, where the rivets had gone through the rope; and that these rivets, instead of being a source of strength, were distinctly a source of weakness. The cap, with rivets through the rope, was then discarded, and he adopted the type now generally used, in which iron cones were applied in halves and the wires of the ropes turned back over them: the cap, being then closed on and held in position by collars, well driven down. This latter type was used until quite recently, when he increased the margin of safety of the winding-ropes from 8 to 10 times the working-load. In connection with this, it seemed rather absurd to be increasing the strength of the winding-rope to 10 times the working-load, when the strength of the cap was not known; and, accordingly, a series of tests were made to ascertain the strength of the cap. He was surprised to find that in the first case only 58 per cent., and in the second case only 65 per cent.,

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of the breaking-strain of the rope was obtained. This was considerably less than it ought to be, although the caps were made in the usual way by a thoroughly good blacksmith, under the supervision of a capable enginewright. He then had a number of caps made for testing purposes, increasing in solidity each time, until this form of cap was eventually able to withstand 90 to 95 per cent. of the breaking-strain of the rope.

Whilst engaged in these tests, he reverted to the solid cap, and thought that it would be still better if the full strength of the rope could be obtained. He accordingly had further tests made, and found that it was only a question of the composition of the white metal; certain alloys proved too soft, but various others were found to give the full breaking-strain of the rope. Mr. Gerrard had communicated to him the composition of an alloy, which gave the full strain of the rope; and it had the further advantage of a comparatively low melting-point. Some engineers might be nervous about adopting the solid cap, the strength not being so obvious and mechanically apparent as the form that they were accustomed to use; but it was only a matter of gaining experience and of becoming accustomed to it—especially by seeing one or two caps tested to destruction, and observing how they behaved.

With respect to the cap invented by Mr. Becker, it appeared to be designed on the lines of the grips, used in certain proving-houses, for quickly getting hold of ropes brought for testing. There, the strength of the grips depended upon the pressure applied to the circumference of the rope. This form of cap did not get hold of the internal wires, except by the pressure applied to the circumference of the rope by the circular wedges as they tightened. He (Mr. Pickup) feared that, with a locked-coil rope, the inner rings would be liable to be withdrawn.

Mr. H. H. Bolton said that he would like to corroborate what Mr. Pickup had said about a capping of the form introduced by Mr. Becker not being adapted for use with locked-coil ropes. The grips used for testing ropes at Dudley were similar to it, the outer wires were broken during the test, leaving the inner wires intact, and the rope became so much weaker. The cap might be feasible for use with ordinary ropes, but he certainly did not think that it would be useful in the case of locked-coil ropes.

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The PRESIDENT (Mr. Gerrard) remarked that he had seen a Becker cap tested, and the rope broke just within the first hoop, where the nip was, at about 98 per cent. of the efficiency of the rope. In other words, it broke at rather less than the full breaking-strain.

Mr. WILLIAM PICKUP said that, although he had not known a cap of the usual construction to fail in actual work, and had not heard of one failing, it did not dispose of the fact that, although most engineers were satisfied with these caps, they were surprised to find their weakness on going into the question. When one or two caps had been tested, and found to give only 50 or 60 per cent. of the breaking-strength of the rope, he thought that there was ample room for improvement. And if, at the same time, another type of cap could be got, which would give the full breaking-strain of the rope, it ought to be considered as being much more suitable for use. He thought that confidence in the strength of the solid cap would come from experience in use.

The PRESIDENT (Mr. John Gerrard), in closing the discussion, thanked the members who had taken part therein, and the many friends who had so kindly supplied him with the results of tests and much valuable information. Mr. W. Pickup stated that "he had not known a cap of the usual construction to fail in actual work, and had not heard of one failing." It was by reason of several failures in actual work that his (Mr. Gerrard's) attention was directed to this question; when he read the admirable paper by Mr. W. C. Blackett on his method of socketing a winding-rope,* it appeared to him that the method deserved serious consideration; and he had found that Mr. Blackett's strictures and condemnation of the ordinary methods of capping ropes were fully justified. He might be permitted briefly to allude to several points, which appeared to him to be prominent in connection with this subject. It appeared to be conceded that the form of capping which depended upon rivets was liable to damage the ropes; that the capping which depended upon a bulge, formed by turning back the wires of the rope, the cap being gripped by a number of hoops, had been proved by a

* "A Method of Socketing a Winding-rope," by Mr. W. C. Blackett, *Trans. Inst. M. E.*, 1901, vol. xxiii., page 10.

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number of tests to be unreliable: only 50 to 60 per cent. of the strength of the rope being ordinarily obtained by this method; and that the solid-metal cap had been proved by repeated tests to give a strength greater than that of the rope. Various views had been expressed as to the practicability of this method; it had been stated that ordinary colliery-blacksmiths could not be trusted to make this cap. His answer to that was, that, where this method was in operation, the ordinary colliery-blacksmith had proved that he could be trusted to do the work. In conversation, these men had expressed their view that they preferred this method to the old one; the results were more reliable than when they had to depend upon the care called for in bending back the wires, in wrapping them, and in driving the tightening encircling hoops home. It had been stated that the heat of the molten metal would affect the temper of the wires of the rope; but experience had proved that there was no foundation for this fear. They had moved very slowly in these matters; but it was very gratifying to him to find that a number of mining engineers were resolved to prove for themselves whether the old method of capping ropes could be depended upon, and were sending caps to be tested. A year ago, he drew the attention of the President of the Midland Institute of Mining, Civil and Mechanical Engineers to this subject, whereupon Mr. T. W. H. Mitchell wrote two papers, and initiated several very interesting discussions.*

Mr. GERALD H. J. HOOGHWINKEL read the following paper on "Electric Pumping at Collieries":—

* (1) "Notes on Capels for Winding-ropes," by Mr. T. W. H. Mitchell, *Trans. Inst. M. E.*, 1905, vol. xxix., page 173. (2) "Further Notes on Capels for Winding-ropes," by Mr. T. W. H. Mitchell, *Ibid.*, 1905, vol. xxx., page 239.

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ELECTRIC PUMPING AT COLLIERIES.

By GERALD H. J. HOOGHWINKEL, M.Inst.Elect.E.

One of the first applications of electric power to the driving of mining plant was the electrically-driven mining pump. The disadvantages of steam as a direct motive-power are obvious, if one only considers underground pumps and shaft-sinking pumps, with long and leaky steam-ranges, obstructing the shaft to such an extent that shaft or pipe-repairs become exceedingly difficult, without stopping the pumps. These disadvantages, together with the high cost of the steam-installation and the heavy repairs, have given the first impulse for the use of electricity in the underground workings of collieries.

The writer proposes, for the present, to deal with underground pumps only, because they are quickly superseding surface-engines and show the many advantages of electric driving, to a greater extent, although the benefit to be derived by using electricity for surface-work is in no way diminished.

It will not be necessary to repeat the disadvantages of placing steam-driven pumps underground, where the use of steam and the increase of temperature always constitute a danger. In the deep workings of the future, the use of steam-driven pumps for underground work is an impossibility.

Pumps.—The only types of pumps available, until recently, were slow-speed ram, piston- or bucket-pumps, according to the lift required; but on account of the shorter strokes and smaller masses to be moved, underground direct-driven steam-pumps were worked at higher speeds than surface-pumps. However, even these comparatively low speeds were not very suitable for coupling to electric motors without the use of gearing. As gearing was thought to be objectionable by most mining engineers, a prejudice which is not shared by the writer, the electrical engineer was asked to reduce the speed of his motor to such a point that two of the great advantages of electric

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motors, namely, cheapness and small dimensions, almost disappeared. The writer has installed many geared pumps of large dimensions, and they are running satisfactorily and without noise. For small pumps, belt-driving with high-speed motors, which show a high efficiency at various loads, may be used, at least in pump-rooms where the atmosphere is not too much saturated with moisture.

The desire to use moderately high-speed motors resulted in the design of high-speed pumps, such as the Riedler, the Bergman, and several others, using mechanically-aided valves, operated by levers, cams or excentrics. These high-speed pumps were to be used for high lifts; but lately the speed has been reduced, so as to ensure absolute security from breakdowns owing to valve-troubles, etc. For pumping-plant, especially at mines, safety from breakdown is the one and only condition which must be satisfied before everything else, even before high efficiency; and, as will be seen later on, the electric motor has been instrumental in bringing into favour a class of pumping machinery which fulfils this condition, and so far had been very rarely used for underground pumping. The first Express pump of large capacity was run at 200 to 300 revolutions per minute, but this speed has been gradually reduced to 120 to 180 revolutions, which is an immense advance on the old-fashioned slow-speed pumps at 50 to 80 revolutions, and still allows of the use of electric motors of fairly economical design and low first cost.

For small pumps, the speed may be somewhat higher, and for such pumps belt-driving is advisable, if there is enough space in the pump-room: the loss in the belt being equalized by the higher efficiency of the motor.

The latest electrically-driven mining pump (in the opinion of the writer, destined to supersede all other pumps and first of all the steam-driven pump) is the electrically-driven high-pressure centrifugal pump. The centrifugal pump is, of course, an ideal mining pump, on account of its many and valuable qualities, namely:—(1) Cheapness, about one-sixth; (2) small dimensions and compactness; (3) strong construction and almost absolute security from breakdown; (4) possibility of pumping dirty and gritty water; and (5) small pump-room required. The commercial construction of high-pressure centrifugal pumps is of

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recent date, and is due almost entirely to Messrs. Sulzer Brothers of Winterthur. Now, any lift can be attained up to 750 feet with one pump only; and for higher lifts, with two or more pumps in series.

The first large installation erected on this principle was the pumping-plant for the Hocayo mines, Spain. Small centrifugal pumps, driven by electric motors, were installed on each pumping-level as the workings increased in depth. The pumps needed no supervision, and the loss of energy, usually incurred by letting the water flow and accumulate in the sump at the pit-bottom, was avoided. Another advantage was that the capacity of the installation could be gradually increased, with very little cost. With plunger-pumps, either steam or electrically driven, a

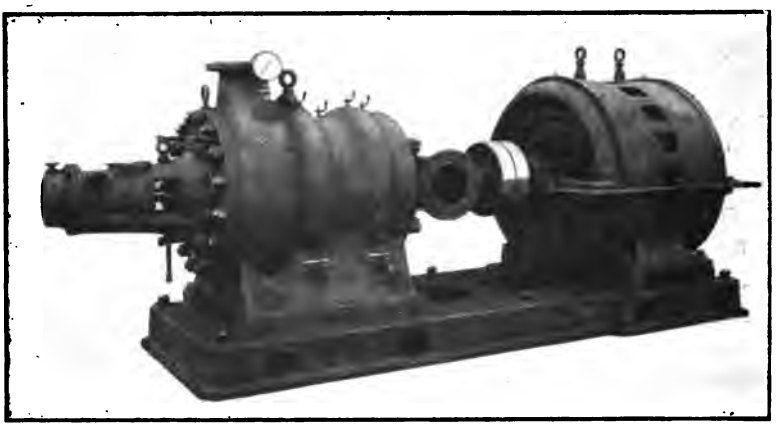

FIG. 1.—UNDERGROUND ELECTRIC PUMPING PLANT AT THE EMS LEAD-MINE: THE SULZER CENTRIFUGAL PUMP WILL RAISE 550 GALLONS OF WATER PER MINUTE TO A HEIGHT OF 837 FEET, AND THE MOTOR OF 225 HORSEPOWER RUNS AT 1,465 REVOLUTIONS PER MINUTE.

division of the pumping-plant in this manner would be impossible, owing to the high cost and still higher working costs. The water pumped from its proper inflow-level is also much clearer, and has therefore a certain value when brought to the surface.

Modern high-pressure centrifugal pumps may be divided into two distinct classes, namely, the Sulzer pump and the Rateau pump. Various firms on the Continent and in the United States manufacture either of these types on licence, or a pump of their own, which may be more or less a combination of both principles.

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The Sulzer pump consists of one or more rotating impellers, containing spirally-curved guide-blades and fixed guide-wheels, provided with spirally-curved water-passages. The water is thrown radially against the fixed guide-wheels and through openings in the latter, back again against the blades of the next propeller, which throws it through openings in the periphery of the fixed guide-wheel in the pressure-chamber surrounding the guide-wheels. Thence, the water flows through channels to the next impeller-system or to the discharge, if it is a single-stage pump. Gradually the velocity is transformed into pressure by means of expanding channels. This pressure varies of course with the speed of the impellers, but it may be taken as about 225 feet of head per impeller-stage. With four impellers, therefore, a head of 800 feet may be taken as normal (Fig. 1). For higher lifts,

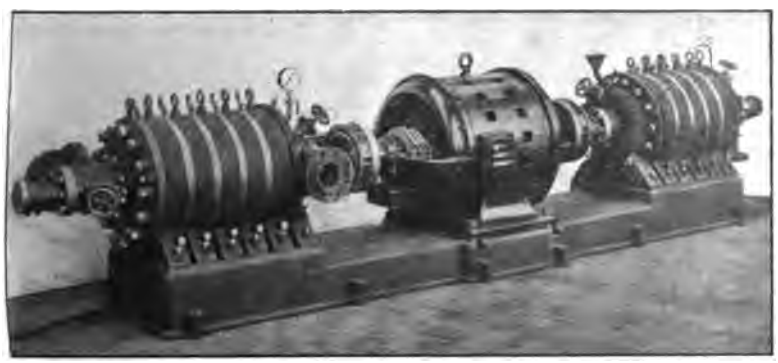

FIG. 2.—UNDERGROUND ELECTRIC PUMPING PLANT AT THE BLIESENBACH COLLIERY: THE TWO SCHWARZKOPF CENTRIFUGAL PUMPS IN SERIES WILL RAISE 220 GALLONS OF WATER PER MINUTE TO A HEIGHT OF 1,083 FEET, AND THE MOTOR OF 106 HORSEPOWER RUNS AT 1,450 REVOLUTIONS PER MINUTE.

two pumps in series, coupled to one motor in the centre, may be used with advantage (Fig. 2). The impellers and the guide-wheels are made of bronze. The axle, of nickel-steel, is supported on two self-oiling bearings. Another great advantage is the ease with which the wheels can be changed, and even with the largest sizes, it does not take longer than 2 hours. Only spare impellers and guide-wheels need, therefore, be kept in reserve, instead of a complete pumping set, as with plunger-pumps. The pumps are coupled to the motors by means of elastic couplings. The suction-pipe is provided with a safety-valve and foot-valve. The former prevents the water in the rising-main from entering the pumps and pressing against the foot-valve.

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The first important installation of centrifugal pumps of high capacity against a head of over 1,800 feet placed at the pit-bottom was carried out at the Victor-Rauxel colliery, Westphalia (Fig. 3). Two pumps are installed in series, each having a capacity of 1,500 gallons of water per minute against a head of 900 feet. This plant has now been running for two years, night and day, without a single hitch. An official test showed the following results:—Steam-engine, 90 per cent.; generator, 94 per cent.; cables, 99 per cent.; motor, 93 per cent.; and pumps 75 per cent.; the total efficiency being 59 per cent.

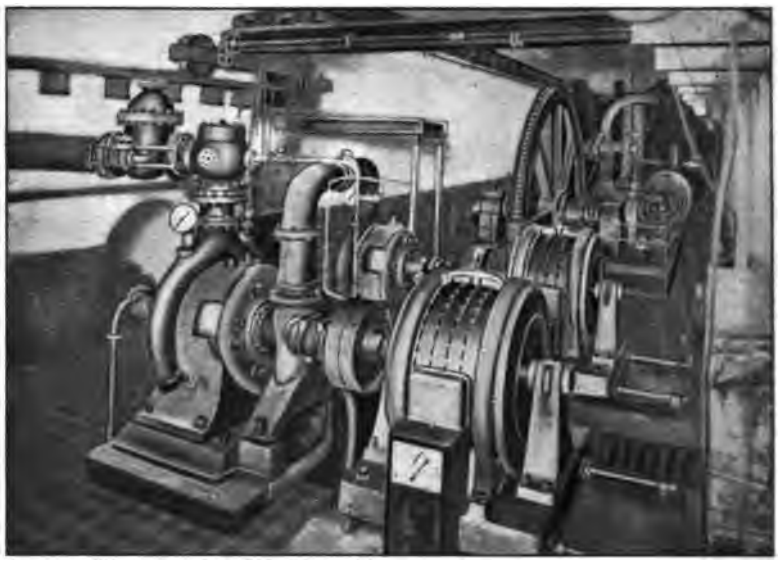

FIG. 3. UNDERGROUND ELECTRIC PUMPING PLANT AT THE VICTOR-RAUXEL COLLIERY: THE TWO SULZER CENTRIFUGAL PUMPS IN SERIES WILL EACH RAISE 1,500 GALLONS OF WATER PER MINUTE TO A HEIGHT OF 900 FEET, AND THE TWO MOTORS EACH OF 600 HORSEPOWER, AT 5,000 VOLTS, RUN AT 960 REVOLUTIONS PER MINUTE.

The Rateau pump is built on another principle, as the water does not leave the impellers in a radial direction, but in an axial one. In the Sulzer pump, the water flows on the impellers in an axial direction and is thrown out radially; but, in the Rateau pump, the water enters the passages of each impeller at the centre and, by the rotation, is forced out to a collecting-chamber surrounding the periphery of the impeller. The ducts which return the water back to the centre of the impeller are suitably curved

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to act as guide-passages, similar in action to the guide-buckets of a turbine. The water then enters the impeller in an axial direction, its rotary motion having been transformed by the guide-passages into rectilinear motion. Many pumps have been built on the Rateau principle, in Germany as well as in the United States; and a combination of the Sulzer and Rateau pumps forms the Schwarzkopf pump. Centrifugal pumps are mostly provided with a special balancing arrangement (that of the Sulzer being kept secret), usually consisting of a hollow plug, at the bottom-chamber, adjusted by screws, causing the impeller-system to balance by the reaction of the water. This compensates the resulting end-thrust in horizontal pumps, and in a vertical (sinking) pump the excess pressure of the water.

The efficiency of the Rateau pump is slightly higher than that of the Sulzer pump, and may be taken as between 65 and 80 per cent. It can be used for pumping smaller quantities of water at greater heads, while the Sulzer pump is more adapted for large quantities and lower heads. So far as their appearance and construction are concerned, the Sulzer pump has few wheels of large diameter, while the Rateau pump has many wheels of small diameter: in fact, it closely resembles the Parsons turbine. The number of wheels on a Rateau pump, for a head of 600 feet, varies from 8 to 10, necessitating a long pump-body and a high speed. In fact, the increase of pressure per wheel in a Rateau pump is about 1·5 to 2 atmospheres, while in a Sulzer pump it reaches 25 atmospheres.

A recently installed Rateau pump in the Carmaux colliery, France, has a capacity of 80 gallons per minute to a vertical head of 1,350 feet, at a speed of 2,900 revolutions per minute.

Electric Motors.—The electrical part should consist of a high-speed three-phase motor, because it is the cheapest and best-adapted electric motor for mining purposes, and may be worked up to an output of 100 horsepower without a starting switch. Instead of the latter, it is equipped with a centrifugal compensator, which can be made completely gas-and-water tight, and it cuts out the starting resistances automatically. The point is to construct a motor running at a medium speed, and well ventilated so as to show no high temperature-rise after a 24 hours' run. Another required condition is the possibility of

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regulating the position of the stator part of the motor, as the small clearance between the rotor and the stator with three-phase motors (continuous-current motors are not very suitable for underground pumping) soon necessitates a readjustment of the clearance, after continuous running, perhaps for months, without stopping. For large motors, it is essential that they be constructed in many parts, so as to permit of easy transport in the shaft and narrow roadways. Motors of a capacity of 200 horsepower and more should be provided with slip-rings, and these can be completely enclosed, so as to be water-and-gas tight. They must be so well ventilated that, after continuous running for any considerable length of time, their temperature-limit is not reached.

A three-phase motor of modern construction may be considered free from breakdown, and it is therefore not necessary to provide spare units. It is good practice to mount the motor between two pumps, one being a spare, or between the two cylinders of a two-cylinder pump. Direct driving, although not absolutely necessary, is to be preferred, especially for large sets. If gearing is used, bronze wheels and raw-hide pinions should be employed in order to avoid noise, which is most objectionable in a mine, and constitutes a real danger. The motor may also be mounted side by side with a three-cylinder pump, but this arrangement has the disadvantage that all parts of the pump are not so easily reached as with the motor placed in the centre. In the former case, however, the motor should be provided with a revolving mass, either in the rotor or in the shape of a separate fly-wheel, so as to ensure an even turning moment.

Of course, where existing slow-speed steam-pumps have to be converted into electrically-driven pumps, special motors must be built, and this sometimes necessitates very special designs. In a case within the writer's experience, a steam-driven pump, making 68 revolutions per minute, had to be converted by replacing the steam-cylinder by a 150 horsepower three-phase motor, working at a periodicity of 21 and therefore requiring 38 poles. This again required a large stator, which had to be especially stiffened by means of end-shells, so as to ensure safety from breakdown with a clearance of only 0·07 inch.

Specially stiffened frames, however, are very expensive, and a very small clearance is in every way undesirable from a

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running point of view. This may be avoided by using a motor with a double armature, having about half the diameter of an ordinary slow-speed motor, but more than double the length, which is no disadvantage. Two rotors and two stators are placed next to each other and combined into one. Each stator and each rotor has, therefore, half the normal windings and half the number of poles. This construction has still another advantage. We may cross-connect, or rather exchange the electric junctions of the one rotor for the other stator winding, namely: if we connect directly the right-hand rotor winding to the left-hand stator winding, both forming, therefore, a short-circuited winding without slip-rings, and may be former wound. The second half of the secondary winding is on the right-hand stator and may, therefore, be ended at fixed terminals. The stator may be connected to a three-phase starter. The motor has, therefore, no slip-rings, and is eminently suitable for use in fiery mines.

Much depends, of course, on the regularity of the pumping. If the flow of water to be removed is constant, then the pumps can be run direct from the mains of a power-station. In small pumping-plants, if the flow varies very much, the pumps may stand idle during the hours of less flow, but with large installations this is hardly practicable. In the latter case, the pumping-plant must have its own electric generating-plant at the power-station, namely: its own dynamo and spare plant, so as to regulate the speed of the pump by influencing the generator-field through a separate exciter, and also the steam-engine speed. This ensures a speed-regulation without incurring the losses of a speed-control through resistances. This arrangement is only, however, to be recommended for large pumping-plants (300 to 500 horsepower) as the generator-units in the power-station will be about that size. In both cases, however, employing either a separate dynamo or direct driven from the mains, there should be a starting arrangement in the mine as well, and the motor should be provided with slip-rings. In case of emergency, the man in the pump-room should not be obliged to ring up the power-station, but he should be able to shut down the pumping-plant himself. A telephone should always be installed between the pump-room in the mine, which is used at the same time as a general distributing room for the electrical energy, and the power-station on the surface.

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The pump-room, in the mine, should be built of stone or brick, and as near as possible water-and-gas tight, even in mines which are supposed to be exempt from fire-damp. This brick-chamber must be well ventilated and lighted, and serve at the same time as a distributing-station for the entire colliery, from which the cables to the various workings will radiate inbye.

FIG. 4. TEMPORARY UNDERGROUND ELECTRIC PUMPING PLANT: THE CENTRIFUGAL PUMP WILL RAISE 220 GALLONS OF WATER PER MINUTE TO A HEIGHT OF 328 FEET, AND THE MOTOR RUNS AT 1,450 REVOLUTIONS PER MINUTE.

This may seem expensive and wasteful, but the writer has found it to be a saving in the end, as it is so much easier to keep the electric and pumping-plant in perfect order, and therefore to economize in repairs and minimize the chance of a breakdown. The longer life of the machinery and of the switch-gear are also advantages not to be overlooked.

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If the mine is fiery, the switch-gear should be of the gas-tight enclosed type, in the case of starters of the liquid type, while switches and fuses, if any, should be of the oil-type. The short-circuiting contacts of the liquid starters should be enclosed, and the starter itself provided with a dash-pot, so as to prevent it from being put in or opened too quickly. The switch-gear should be protected from accidental contact on the part of the workmen, although the pump-room should be closed to them.

A central telephone-station should be installed, so as to enable the electrician in the pump-room to be warned in time if any acci-

FIG. 5. UNDERGROUND ELECTRIC PUMPING PLANT AT THE NEU-ISERLOHN COLLIERY: THE TWO RIEDLER EXPRESS PUMPS WILL EACH RAISE 400 GALLONS OF WATER PER MINUTE TO A HEIGHT OF 1,350 FEET, AND THE TWO MOTORS EACH OF 200 HORSEPOWER, AT 2,000 VOLTS, RUN AT 180 REVOLUTIONS PER MINUTE.

dent should occur inbye. The instruments must be made of a strong pattern, of the ironclad type, without flexible connections.

A travelling hand-crane should be provided for inspection and repairing purposes. With high-pressure centrifugal pumps, the dimensions of the pump-room may be much smaller, and it is the writer's conviction that for underground pumping the centrifugal high-pressure pump coupled to a three-phase induction motor, is the best combination that can be obtained and is bound to replace even modern steam-pumps (Fig. 4).

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As already mentioned, the induction-motor is much better suited for driving pumps than the direct-current motor, especially if run at a high speed, although it is now quite possible to construct induction-motors with an efficiency of over 92 per cent. running at a speed of 70 to 80 revolutions per minute.

An electric pumping-plant of the three-throw type, capable of raising 1,250 gallons per minute to a height of 1,200 feet, was recently installed at the Kaiserstuhl colliery, Dortmund, driven by an induction-motor of 570 horsepower at 78 revolutions per minute, and taking current at 2,000 volts and a frequency of 22½ cycles per second. The motor was of the flywheel type, in order

FIG. 6. – UNDERGROUND ELECTRIC PUMPING PLANT AT THE RHEIN-PREUSSEN COLLIERY: THE SLOW-SPEED THORIS PUMP WILL RAISE 1,250 GALLONS OF WATER PER MINUTE TO A HEIGHT OF 1,500 FEET, AND THE MOTOR OF 650 HORSEPOWER, AT 2,000 VOLTS, RUNS AT 60 REVOLUTIONS PER MINUTE.

to provide against the uneven torque required for driving the pump, and the slip was therefore about 3 per cent. at normal load. The starting torque required was about 20 per cent. higher than the full-load torque, and this is the chief difficulty in designing induction-motors running at such slow speeds, owing to the magnetic leakage due to the great number of poles.

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Motors of this size are provided with slip-rings, enclosed gas-tight, and with an arrangement to lift the brushes, and short-circuit the windings, when full speed is obtained.

Another modern pumping installation with high-speed Express pumps is placed in the Mansfeld copper-mines at Eisleben. It comprizes four Riedler Express pumps, each having a capacity of 1,250 gallons per minute, with a head of 1,305 feet. They are driven by four induction-motors of 650 horsepower, running at 160 revolutions per minute and 3,000 volts.

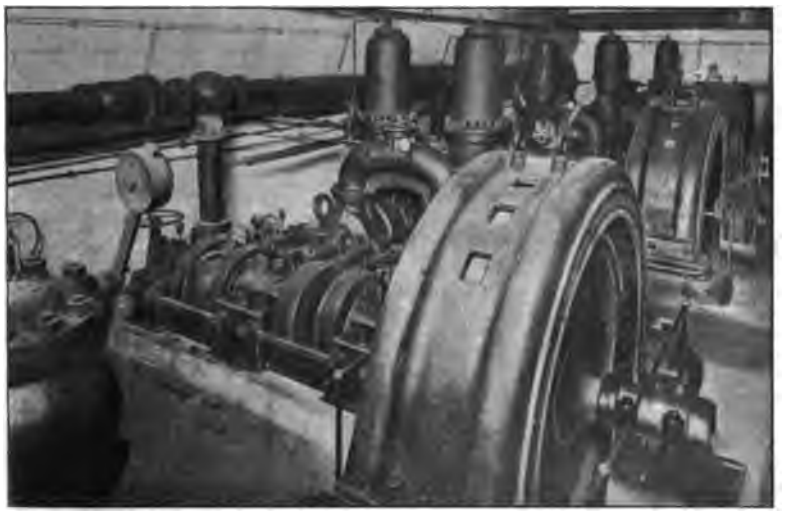

FIG. 7.—UNDERGROUND ELECTRIC PUMPING PLANT AT THE COLONIA COPPER-MINE: THE FOUR RIEDLER EXPRESS PUMPS WILL EACH RAISE 1,100 GALLONS OF WATER PER MINUTE TO A HEIGHT OF 1,350 FEET, AND THE FOUR MOTORS EACH OF 650 HORSEPOWER, AT 3,000 VOLTS, RUN AT 160 REVOLUTIONS PER MINUTE.

Other large modern pumping plants are shewn in Figs. 5, 6, 7, 8 and 9.

Comparison with Steam-pumps.—In order to show clearly the many advantages of electrically-driven pumps placed at the pit-bottom, it may be useful to discuss the claims which conservative mining engineers set up against the electric motor as compared with the steam-engine. A common complaint is that, what is gained by using a slow-speed pump is lost again in the high price of the slow-speed motor. As already pointed out, the pump-makers

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have arrived at a speed for highly efficient pumping machinery (88 per cent. of efficiency) varying between 100 and 200 revolutions per minute: this speed being high enough to enable the electrician to design an efficient electric motor at a reasonable price. This, of course, does not refer to centrifugal pumps, running at speeds which require a cheap electric motor.

Another remark which is often heard is that the electric motor cannot be flooded. Of course no one will claim for the electric motor, at least of any size, that it can work under water for any considerable length of time: this performance being also very difficult for a steam-engine.

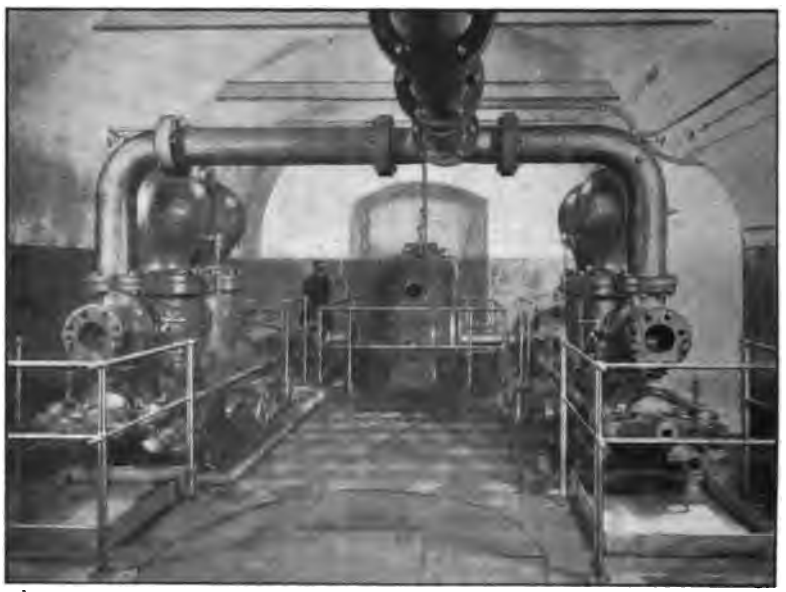

FIG. 8.—UNDERGROUND ELECTRIC PUMPING PLANT AT THE CZERNITZ COLLIERY: THE EXPRESS PUMP WILL RAISE 780 GALLONS OF WATER PER MINUTE TO A HEIGHT OF 825 FEET, AND THE MOTOR OF 260 HORSEPOWER, AT 750 VOLTS, RUNS AT 175 REVOLUTIONS PER MINUTE.

Sinking pumps can be made to work under water for any length of time, and are then in a very much better position than a steam-pump, as the useful cooling effect of the water, in the latter case acts as a condenser. But there should always be sufficient spare pumping-plant at a mine to cope at any time with an increased volume of water, caused by one of the many mishaps which do occur in mines. If, therefore, the pump-room

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be constructed in such a way as to be practically water-proof for at least 3 or 4 feet above the bottom-level, sufficient time will be afforded, in most cases, to lower the water-level, by means of the spare pumps, before the water can enter the pump-room.

With electric pumps it is possible to run them from a central power-station, and to start or shut down in a few seconds without first communicating with the primary power-producing plant. With steam-pumps, it is of course also possible to run several pumps from one battery of boilers; but, in the latter case, the whole of the long steam-range must be kept under steam, which is a most wasteful process, and has many additional disadvantages, such as heating the shaft.

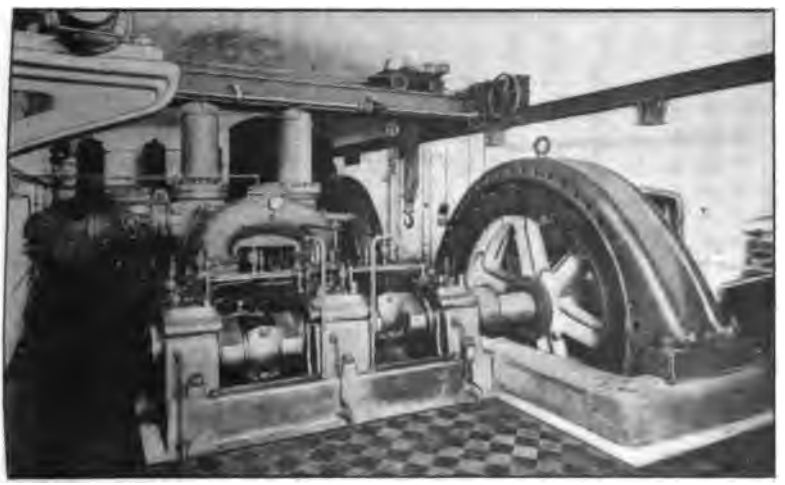

FIG 9.—UNDERGROUND PUMPING PLANT AT THE ENGELSBURG COLLIERY, BOCHUM: THE TWO RIEDLER EXPRESS PUMPS WILL EACH RAISE 550 GALLONS OF WATER PER MINUTE TO A HEIGHT OF 1,800 FEET, AND THE MOTOR OF 700 HORSEPOWER, AT 2,200 VOLTS, RUNS AT 200 REVOLUTIONS PER MINUTE.

With hydraulic pumping-plants, when starting or shutting down any pumps, the speed of the pressure-pump must be regulated in the hydraulic station at the mouth of the mine.

Electric pumping is therefore more flexible, and requires less spare plant, as in a central electric power-station a reserve is kept for the whole of the electric mining plant. It is also possible to erect the central power-station on the most suitable spot, and not necessarily near the mouth of the mine, as is required by steam-plant, in order to have the boilers near the

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winding-engine, the biggest steam-user. Several incidental advantages can be added, namely, the absence of steam-pipes in the shaft, where they are inconvenient and damage the shaft-timbering; and the electric cables may be taken down the upcast-shaft as well as down the downcast-shaft, without interfering with the ventilation.

Working Costs.—In the first place, it may be reckoned that a modern electrically-driven pump does not cost more than a steam-pump. Centrifugal electric pumps cost even less. Therefore, the figures for sinking-fund and interest on capital outlay are not more, and if the cables are set against the steam-pipes, certainly less, than with steam-pumps. In the second place, the repairs of the motors and cables are practically *nil*, and compare very favourably with those of the steam cylinders and pipes of a steam-plant. Further, the most important item in the working-cost figures, is the amount of power taken by the pump; and, therefore, also the efficiency.

Efficiency.—The losses caused by condensation of the steam in the pipes during stops are entirely avoided. When running, the combined efficiency of the pump and the motor is about the same as that of a steam-pump. The same statement holds good if a centrifugal pump is used, as in the latter case, the higher motor-efficiency partly equalizes the lower efficiency of the centrifugal pump. The chief savings are of course effected in the electric station, where an economical high-speed condensing engine may be used, having a much higher efficiency than the pipes and boiler-plant used in running a steam-pump.

A practical average value for an electric pumping-plant of medium size, calculated by the writer from observations of fifteen large electric plants, is 65 per cent. from the steam side of the main engine to the water raised by the pump. This represents from 16 to 18 pounds of steam per horsepower-hour of useful load, an efficiency which is not often reached with steam-pumps.

The individual efficiencies of the different sections of the machinery have been determined, and also constitute a fair average taken over a number of installations, namely, engines, 88 per cent.; dynamos, 93 per cent.; cable, 97 per cent.; motor, 90 per cent.; and pump, 86 per cent.

The efficiency of the Express pump is the highest, rising to

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95 per cent.: this figure being the efficiency of the 500 horse-power Riedler pump at the Hausemann colliery. Other Express pumps show from 90 to 92 per cent. of efficiency.

Centrifugal pumps have a lower efficiency, being about 75 per cent. for Sulzer-type pumps, and 80 per cent. for Rateau-type pumps; but their motor-efficiency is about 4 to 5 per cent. higher, so that at the best, the total combined efficiency is always about 5 per cent. less. The larger the capacity, however, the nearer the efficiencies of the two kinds of pumps approach each other.

The lower costs, however, of the combination-motor and pump, the lower repairs and maintenance-costs, the smaller space and security against breakdowns, are well worth the lower efficiency.

Electric Sinking-pumps.—The conditions under which sinking-pumps must be calculated to work are entirely different from stationary pumps, and therefore they have to fulfil other requirements. Moreover, very little has as yet been done in this particular branch, for which the adoption of electricity possesses some very marked advantages.

Sinking-pumps may be divided into two kinds, (1) one requiring both engine and pump to be slung in the shaft; and (2) where the engine is mounted on the pit-bank, and drives the pump through shafting and rods. The latter kind is the heaviest and most expensive, and is only used where water-bearing strata of quicksand have to be overcome. In this case, large quantities of sand and other impurities have to be lifted by the pump, which would destroy the ordinary high-speed ram-pump with metal valves, in no time, while the slow-speed rod-driven pump fitted with leather or rubber-valves is not much damaged by the sand.

Steam is generally used, and the disadvantage of steam-pumps for sinking purposes are only too well known. There is the low efficiency and the difficulty in ventilating the shaft-bottom and the shaft itself, the room taken up by frequently leaking steam-pipes, which even obstruct the shaft to such an extent, as to prevent the sinkers from doing their work efficiently.

All these disadvantages disappear at once with the introduction of electricity, and one wonders why any steam sinking-pump

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is still used. One of the reasons is, that ram-pumps driven by an electro-motor through gearing, are not only heavy and cumbersome combinations (not more so, however, than steam-pumps) but are also more expensive. It is difficult to render the motor water-tight; and, altogether, when comparing them with pulsometers, where low lifts are concerned, the disadvantages of the steam-pump are forgotten in face of the high cost of the electric pump.

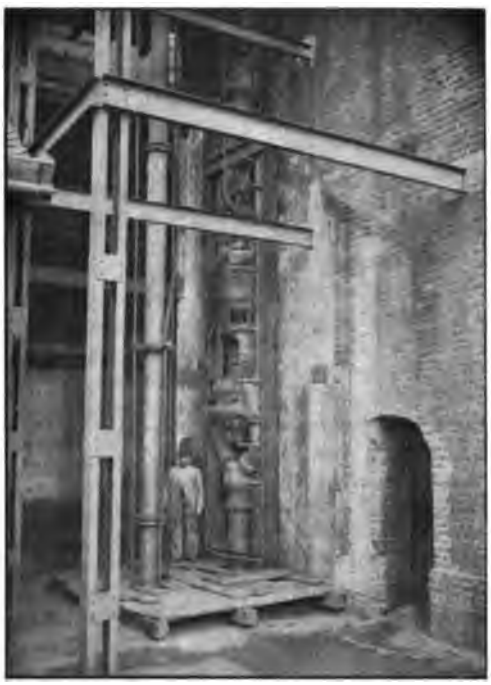

FIG. 10.—VERTICAL ELECTRIC SINKING PUMP AT THE AIX IRON-WORKS: THE CENTRIFUGAL PUMP WILL RAISE 750 GALLONS OF WATER PER MINUTE TO A HEIGHT OF 300 FEET, AND THE MOTOR OF 100 HORSEPOWER RUNS AT 1,450 REVOLUTIONS PER MINUTE.

The introduction of the high-pressure centrifugal pump, with its simplicity, small dimensions, lightness and high speed, has altered the case, and the writer contends that an electrically-driven centrifugal pump is unrivalled for sinking purposes on all points.

The compact design and small dimensions of the electric sinking pump are readily recognized. The construction, though simple, must be carried out in a very thorough manner, and the writer is glad to say that many have now been built on the Continent which yield excellent results.

The motor, mostly three-phase, turns round a vertical axle and must, therefore, be carefully balanced and protected from the dripping water. The weight of the rotating part is carried on a ball-bearing protected by a tightly-closing hood, which also encloses the starting device. The lower bearing is formed by the stuffing-box of the centrifugal pump. The pump-axle is made in one with the motor-shaft, and is supported on another bearing

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fixed in the pump-casing. The bottom part of the motor-casing is shaped in such a way as to form one with the pump, without, however, preventing access to the stuffing-box. The top part of the motor-casing protects the motor against any water-spray. The windings are, of course, extra-insulated, so as not to suffer from dampness in the shaft. The starting device is mounted on the pump, as it is found better to stop and start the pump in the shaft at will, without signalling to the surface. The simplest device is the centrifugal automatic starter, which may be used with motors up to 100 horsepower and can be easily enclosed so as to be air-and-water tight. For powerful pumps, in cases where variations of the voltage are not allowed, starting resistances must be used (Fig. 10).

The pressure and suction-pipes are doubled, while the suction-pipe enters the pump from above, thereby partly doing away with the pressure due to the weight of the rotating masses. This arrangement practically removes all pressure from the ball-bearing.

The entire pumping-set is slung on two chains, hooked into the eye-bolts, which connect the top and bottom parts of the set. The pump-motor and pipes are kept rigidly in line through being connected to the covering of the motor. A steel protecting hood covers the whole pump, and under it are mounted the various regulating appliances, namely, an ammeter, a starter, a main switch, and the stop-valve hand-wheel.

These pumps have a compact and mechanical appearance, and their advantages are calculated to bring them into use in a short time.

The PRESIDENT (Mr. John Gerrard) said that he had seen a large installation of electric pumping machinery in Westphalia, and had the advantage of comparing its work with that of the old steam-pumping plant, which it superseded. He especially noted that the electric installation occupied only one-half the space taken up by the steam-plant, whilst doing the same amount of work.

The cordial thanks of the meeting were given to Mr. Hooghwinkel for his paper.

The discussion was adjourned.

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MANCHESTER GEOLOGICAL AND MINING SOCIETY.

EXCURSION MEETING,
JULY 22ND, 1905.

The members visited the Little Don Valley Water-works, in course of construction by the Sheffield Corporation, under the leadership of Mr. William Watts, Assoc.M.Inst.C.E., F.G.S., engineer of the works.

LITTLE DON VALLEY WATER-WORKS.

The Underbank reservoir, near Stocksbridge, was being made to impound water for purposes of compensation only. The reservoir, when full, is estimated to hold 650,000,000 gallons of water and to submerge 100 acres of land; and the drainage-area flowing into it is 2,336 acres in extent. The length of the embankment is 1,560 feet, and it contains 350,000 cubic yards of earth and puddle. The trench, belowground, forming the foundation for the concrete-core, is 71 feet deep on an average, and is refilled with cement-concrete.

There are a discharge tunnel, 14 feet in diameter, built in the solid on the southerly side; a valve-well, 11 feet in diameter; a waste-weir, 250 feet in length; and a bye-wash, 50 feet wide, formed of ashlar steps in risings of 15 inches from the bed of the river to the top water-level.

The total drainage down to the embankment is 8,698 acres, and the estimated rainfall is 48 inches.

The average elevation is 835 feet above Ordnance datum-level, assuming that the hills were levelled into the valleys represented by the 2,336 acres.

The old highway, which formerly ran in what is now the reservoir-bottom, had been diverted, and a new one formed, 1½ miles long, terminating at Midhopestones; and, in order to facilitate the haulage of goods, a tramway had been constructed, 3½ miles in length, to enable the materials required for the works to be conveyed direct from Deepcar station on the Great Central Railway.

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The surface-geology of the valley is less interesting than its physical features. The upper measures are covered with local débris, denuded from the slopes by the eroding agencies of time, without any admixture of foreign matter indicating a glacial period, or even a submergence beneath the sea since the hills emerged above it, in time too far back for the human mind to measure it with a degree of accuracy sufficient to be understood. No boulders or boulder-clay have been found to mark the boreal conditions of an Arctic climate, such as one finds on the other side of the Pennine ridge in the Lancashire valleys.

The superior strata in which the trench has been cut are in the Lower Coal-measure series, and two seams of coal have been met with at the northerly end, but denudation has removed them from the southerly side of the valley. A fairly large fault was cut through at the northerly end, lifting the measures up on the southerly side, and thus protecting the outcropping edges of the parent beds, which plunge under Penistone.

The Little Don river has a gradient of 1 in 40, from its confluence with the Don at Deepcar to the crest of the Pennine range, a distance of 7 miles. The hills in places attain an altitude of 1,700 feet, and all the way the river is verged by trees.

At Langsett, there is a fine view of the winding course of the Little Don, and in the distance overlooking Stocksbridge, Wharncliffe Crags are seen as beacons of serried rocks, illustrating evidence of hill-erosion. The threshold of the Pennine Chain is here reached, and the slopes rise to the crest in unbroken sequence, which gives a moorland view of rare beauty. The average elevation of the land down to the centre-line of the embankment is 1,281 feet: the zone on which rain-gauges should be placed, so as to obtain a true average of the annual rainfall.

The watershed controlled by the reservoir is 5,203 acres in extent. The floor is fairly impervious, and no important springs exist upon it. In flood-time, the water is of a peaty colour, but the contributory streamlets carry very little denuded material, as the water slides along mainly on indurated channels, which resist wear-and-tear of the ground.

The Langsett reservoir covers 124 acres, and holds 1,400,000,000 gallons. The length of the embankment is 1,144 feet, and it contains about 900,000 cubic yards of earth and

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puddle. The roadway passing over it is 817 feet above Ordnance datum-level. The concrete trench on which the puddle rests is 1,648 feet long, with an average depth of 91 feet below the floor of the valley; the material removed amounts to 47,500 cubic yards, and the excavation has been refilled with 43,000 cubic yards of cement-concrete. The puddle-trench contains 69,500 cubic yards of clay.

The discharge-tunnel is 9 feet in diameter; and the circular valve-shaft is 12 feet in diameter, 100 feet in depth, and contains six valves, 33 inches in diameter, all of which are worked by hydraulic cylinders.

The shale, in which the concrete core is embedded, lies immediately under the rough rock of the Millstone Grit, and attains a thickness of about 200 feet. It yielded a prolific supply of water when first opened out, but does not admit it as spring-water at the surface, the ducts not leading upwards as they do along the bedding-planes. On the south side, the shales are shattered above the floor of the valley, and present innumerable slip-joints, some of which were open, but these lines of fracture do not extend more than a few feet below the solid floor of the river and disappear in the heart of the hill. To get rid of these open joints, the trench was opened to a depth of 170 feet below the ground-level, and carried about 200 feet farther into the hill than the end of the embankment.

The measures in the centre of the valley were found to be a little wavy, but the contorted beds died away in curiously twisted foldings, solidly filled with impervious matter, growing thinner and thinner as they were deepened and finally died away in normal bedding.

The valve-tower on the embankment, the waste-weir, 200 feet in length, the bye-wash, and a stone-arched bridge represent the class of masonry and work carried out in the Little Don valley.

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The entire Series of the Geological Survey Maps on the one-inch and six-inch scale, with Memoirs, of the Lancashire Coal Field, is now complete, and available for reference by the Members.

Catalogue of the Library, price 1s. 6d.

Mr. Dickinson's CHART OF COAL STRATA OF SOUTH LANCASHIRE may be had separately at 6d., or with the part containing the letterpress at 1s. each.

Application for Volumes or Parts of unbound Volumes of the Transactions to be addressed only to the Hon. Secretary, Queen's Chambers, 5, John Dalton Street, Manchester.

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PART V. VOL. XXIX.

TRANSACTIONS

OF THE

MANCHESTER GEOLOGICAL & MINING SOCIETY.

EDITED BY

THE HONORARY SECRETARY.

SESSION 1905-1906.

PUBLISHED AT THE ROOMS OF THE SOCIETY,
QUEEN'S CHAMBERS, 5, JOHN DALTON STREET, MANCHESTER.

PRINTED BY ANDREW REID & CO., LIMITED, NEWCASTLE-UPON-TYNE.

MDCCCCVI.

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JUN 10 1906

MANCHESTER GEOLOGICAL AND MINING SOCIETY.

ANNUAL GENERAL MEETING,

HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS, 5, JOHN DALTON STREET, MANCHESTER, OCTOBER 10TH, 1905.

MR. JOHN GERRARD, RETIRING PRESIDENT, IN THE CHAIR.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. C. MAITLAND KNEEBONE, Mining Engineer, Oakdale, Grove Park West, Colwyn Bay.

Mr. F. J. THOMPSON, Mine Manager, United Alkali Company, Fleetwood.

ASSOCIATE MEMBER—

Mr. EDWARD THOMAS MELLOR, Geological Survey Office, P.O. Box 435, Pretoria, Transvaal.

STUDENT—

Mr. CHARLES OLIVER CROSS, 2, Percy Road, Wrexham.

The Annual Report of the Council was read as follows:—

ANNUAL REPORT OF THE COUNCIL, 1904-1905.

The Council, in presenting the sixty-seventh Annual Report on the position and work of the Society, have much pleasure in recording the satisfactory progress which has been made during the sessional year.

The Annual Meeting and eight Ordinary Meetings were held in the Society's rooms. The attendances were very good.

The membership of the Society has been increased by the election of 2 honorary members, 39 members, 3 associate members, 1 associate and 3 students, amounting to a total increase of 48. The losses by death and resignations amount to 13, of which death claims 6. As compared with the preceding year, there has been a net gain of 35 members.

Among the deaths, which the Council regretfully record, are those of Mr. George Peace, the late managing director of the

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Astley and Tyldesley Collieries, Limited, who for many years was a member of the Council; Mr. H. H. Bolton, a colliery proprietor and a member of the Society for many years; Mr. Thomas Banks; Mr. W. Holding; Mr. C. G. Jackson; and Mr. W. W. Millington.

Mr. Mark Stirrup, F.G.S., and Mr. Herbert Bolton, F.R.S.E., were nominated by the Council to become honorary members, in consideration of their valuable services to the Society, and were duly elected at the November meeting.

The classification of the membership is shewn in the following table:—

Classification.	Non-federated Members.	Federated Members.	Totals.
Honorary Members	11	—	11
Members, inclusive of Life Members	80	175	255
Associate Members	—	3	3
Associates	—	2	2
Students	—	7	7
Totals ...	91	187	278

In his Presidential Address, Mr. John Gerrard referred to the federation of the Society with The Institution of Mining Engineers, and to the great advantage which the Society now possessed for promoting its objects, namely, the collection and diffusion of knowledge respecting geology and mining; also to the many local geological problems which remain to be solved; the working of seams of coal; the temperatures met with at great depths both at home and abroad; power-transmission in mines by compressed air and by electricity; and to the great improvement in the death-rate of persons employed in connection with the mining industry, as shewn by Government statistics.

During the session, valuable papers and short communications have been read before the members on geological subjects by Mr. James Ashworth, Mr. Walter Baldwin, F.G.S., Prof. W. Boyd Dawkins, M.A., D.Sc., F.R.S., J.P., etc., and on mining, electrical and mechanical engineering subjects by Mr. James Ashworth, Mr. Joseph Dickinson, F.G.S., Mr. Gerald H. J. Hooghwinkel, Mr. Arthur Ross, F.C.S., F.I.C., Mr. John J. Whitehead, Mr. G. J. Williams, H.M.I.M., F.G.S., and Mr. George H. Winstanley, F.G.S. An instructive discussion on the various methods of capping wire-ropes was introduced by the President, Mr. John Gerrard.

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Mr. James Ashworth exhibited specimens of coal-dust obtained from the Morrissey mine, British Columbia; and Mr. John Gerrard exhibited fossil remains and specimens of coal obtained from the new coal-winning at Dover; also specimens of coal-dust found in the Morrissey, Shelton and Broad Oak collieries respectively. A model of a new roller belt-conveyor was exhibited by Mr. Wm. Hy. Johnson, B.Sc.

The complete list of the papers and other contributions is as follows:—

"Notes on the Crow's Nest Coal-field, British Columbia." By Mr. James Ashworth.

"Outbursts of Gas and Coal at the Morrissey Collieries, British Columbia." By Mr. James Ashworth.

"The Hunter V. Mine, British Columbia." By Mr. James Ashworth.

"*Prestwichia anthrax* and *Belinurus lunatus* from Sparth Bottoms, Rochdale." By Mr. Walter Baldwin, F.G.S.

"A Section of the Glacial Deposits met with in the Construction of the New Docks at Salford," made by Mr. W. H. Hunter. By Prof. W. Boyd Dawkins, M.A., D.Sc., etc.

"The Permian and Carboniferous Rocks in a Section in High Street, Chorlton-on-Medlock, Manchester." By Prof. W. Boyd Dawkins, M.A., D.Sc., etc.

"Mountain Tunnelling." By Mr. Joseph Dickinson, F.G.S.

"Church in Coal-mines." By Mr. Joseph Dickinson, F.G.S.

"Presidential Address." By Mr. John Gerrard, H.M.I.M.

"Electric Pumping at Collieries." By Mr. Gerald H. J. Hooghwinkel.

"The Circulation of Water in Steam-boilers." By Mr. Arthur Ross, F.C.S., F.I.C.

"Notes on Coal in the Transvaal." By Mr. John J. Whitehead.

"A Safety-brake for Hand-cranes." By Mr. G. J. Williams, H.M.I.M., F.G.S.

"A Fatality caused by Low-pressure Electric Current in a Lancashire Colliery." By Mr. George H. Winstanley, F.G.S.

The year in review being the first in which the Society has been federated with The Institution of Mining Engineers, it will be of interest to the members generally to know that the result has been beneficial to the Society. The number of new members (48) elected during the year is probably an unexampled record, while from the financial point of view the result, as shewn by the Treasurer's statement of accounts, has been equally satisfactory.

The Council desire to draw the special attention of the members to the important fact that the rules of The Institution of Mining Engineers, relating to its publications, have been amended, so as to include "applied geology" as a subject for papers. This, for the first time, places papers on practical

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geological subjects on an equal footing with those on mining subjects, for insertion in the *Transactions* of The Institution of Mining Engineers, and relieves the Manchester Geological and Mining Society from the necessity of printing such papers at its own expense. It is hoped that the effect of this change will be to encourage members to continue such contributions.

The arrangements in connection with the Annual Meeting of the members of The Institution of Mining Engineers, held in the Town Hall, Manchester, by the kind permission of the Lord Mayor (Sir Thomas Thornhill Shann), on September 13th, 1905, and the excursions made to various works in the neighbourhood on September 14th, 15th and 16th, 1905, were made by your Council; and Sir Lees Knowles, Bart., M.P., one of your representatives, was elected to the office of President of the Institution for the year 1905-1906.

On July 22nd, 1905, the members made an excursion to Underbank and Langsett, near Penistone, to revisit the Sheffield Corporation's water-works in the Little Don valley, under the leadership of Mr. William Watts, Assoc.M.Inst.C.E., F.G.S., the engineer of the works. Mr. Watts addressed the members present, and described the scheme generally; and, with the aid of detailed drawings, illustrated the progress made from time to time during the construction of the works, extending over a series of years.

The usual presentations from kindred societies with whom transactions and periodicals are exchanged continue to be received; and these, together with the Library, are available for reference on week-days between the hours of 9·30 a.m. and 5·30 p.m., except on Saturdays, when the rooms are closed at 1 p.m.

In conclusion, your Council desire to express their indebtedness to all those who have so ably assisted by reading papers and taking part in the discussions thereon, and it is hoped that the members generally will endeavour to bring the Society to the notice of their friends, and otherwise assist in maintaining the high reputation of the Manchester Geological and Mining Society.

The Honorary Treasurer (Col. G. H. Hollingworth) presented the annexed Statement of Accounts and the balance-sheet for the past year.

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Dr. The Treasurer in Account with the Manchester Geological and Mining Society, for the Year ending September 30th, 1905. Cr.

	£	s.	d.	£	s.	d.
Sept. 30th, 1904.						
To Balance in bank				105	12	6
,, ,, in Secretary's hands				6	14	4
Sept. 30th, 1905.						
To Members' subscriptions:—						
Arrears				30	0	0
Current:	£	s.	d.			
1 Life-composition				15	0	0
Donation, Dr. Black...	2	2	0			
157 Members	330	16	0			
3 Associate Members	6	6	0			
2 Associates ...	2	10	0			
7 Students	8	15	0			
50 Non-federated Members ...	50	2	0			
3 Subscribers ...	3	0	0			
				403	11	0
In Advance				3	2	0
						451 13 0
To Dividends:—						
Birkenhead Railway				22	16	0
Lancashire and Yorkshire Railway				20	17	10
						43 13 10
To Bank-interest, less commission						1 14 6
To Hire of rooms						3 8 6
To Sales of *Transactions*						1 15 0
						£614 11 8

	£	s.	d.
Sept. 30th, 1905.			
By Rent, wages, and expenses of rooms	133	19	8
,, Printing and stationery	26	15	3
,, Postages, etc.	16	14	6
,, Reporters	10	10	0
,, Library	5	12	2
,, Sundry expenses	11	12	9
,, *Transactions* of The Institution of Mining Engineers	175	18	0
,, Printing *Transactions*, 1903-1904	76	12	6
,, Expenses of meetings	22	11	2
,, Balance in bank	131	19	4
,, ,, Secretary's hands...	2	6	4
	£614	11	8

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Dr. Library Fund. Cr.

	£ s. d.		£ s. d.
Sept. 30th, 1904.		Feb. 28th, 1905.	
To Balance, brought forward	4 17 5	By Books	3 5 8
Dec. 30th, 1904.		,, Balance, carried forward	1 13 9
To Bank-interest	0 2 0		
	£4 19 5		£4 19 5

Balance Sheet, September 30th. 1905

Liabilities.	£ s. d.	Assets.	£ s. d.
Outstanding accounts, say	10 0 0	£600 Birkenhead Railway 3 per cent. Consolidated Preference Guaranteed Stock, at £122	732 0 0
Balance in favour of the Society	2,069 4 5	£733 Lancashire and Yorkshire Railway 3 per cent. Consolidated Preference Stock, at £90¼	661 15 0
		Library and furniture	500 0 0
		Cash in bank	131 19 4
		,, in Secretary's hands	2 6 4
		Arrears of subscription, £84, say	42 0 0
		Accounts owing	7 10 0
		Balance of Library Fund	1 13 9
	£2,079 4 5		£2,079 4 5

The Investments of the Society consist of £600 Birkenhead Railway 3 per cent. Consolidated Preference Guaranteed Stock, and £733 Lancashire and Yorkshire Railway 3 per cent. Consolidated Preference Stock. The certificates for these are deposited at the Williams Deacon and Manchester and Salford Bank, St. Ann's Street, Manchester, and were inspected by us on October 10th, 1905.

Audited and found correct, October 10th, 1905.

Geo. H. Hollingworth,
Honorary Treasurer.

Jon. Barnes,
G. H. Winstanley, } *Auditors.*

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The RETIRING PRESIDENT (Mr. John Gerrard) said that the accounts were most satisfactory and reflected great credit on the Society's indefatigable treasurer, Mr. Hollingworth. There was a cash-balance in favour of the Society of £130; there was about £2,000 in reserve; and, without taking account of stock, library, etc., there was some £1,500 to the good.

The report and accounts were unanimously approved, on the motion of Mr. CHARLES PILKINGTON, seconded by Mr. R. WINSTANLEY.

ELECTION OF OFFICERS, 1905-1906.

The following officers were unanimously elected for the ensuing year:—

PRESIDENT:

Mr. HENRY BRAMALL, M.Inst. C.E.

VICE-PRESIDENTS:

Mr. JOHN ASHWORTH, C.E.	Mr. D. H. F. MATHEWS, H.M.I.M.
Mr. GEORGE B. HARRISON, H.M.I.M.	Mr. CHARLES PILKINGTON, J.P.

HONORARY TREASURER: Mr. G. H. HOLLINGWORTH, F.G.S.

HONORARY SECRETARY: Mr. SYDNEY A. SMITH, Assoc.M.Inst.C.E.

COUNCILLORS:

Mr. H. STANLEY ATHERTON.	Mr. GEORGE H. PEACE, M.Inst.C.E.
Mr. C. F. BOUCHIER.	Mr. WILLIAM PICKSTONE.
Mr. VINCENT BRAMALL.	Mr. P. C. POPE.
Mr. A. DURY MITTON, Assoc. M.Inst.C.E.	Mr. ALFRED J. TONGE.
	Mr. JESSE WALLWORK.
Mr. W. OLLERENSHAW.	Mr. L. B. WELLS, M.Inst.C.E.

Mr. GEORGE H. WINSTANLEY, F.G.S.

HONORARY AUDITORS:

Mr. J. BARNES, F.G.S.	Mr. GEORGE H. WINSTANLEY, F.G.S.

Mr. HENRY BRAMALL, in taking the presidential chair, thanked the members for having placed him in the responsible position of President, and said that he would do his best to fulfil the duties

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satisfactorily. He was very pleased to think that he would have the assistance of the members of the Council and the officers of the Society, and but for that assurance he would hardly have dared to undertake such responsibilities. He might find it difficult to attend all the meetings, but he asked for their forbearance on the occasions of his absence.

He (Mr. Bramall) had pleasure in proposing a vote of thanks to the Retiring President. The members were very much indebted to Mr. John Gerrard for the interest that he took and had always taken in this Society. He had fulfilled the duties of his office, during a year which had been rather eventful, in a way that had been perfect.

Mr. C. PILKINGTON, in seconding the motion, said that Mr. Gerrard had done a great deal for the Society. During the visit in September of The Institution of Mining Engineers to Manchester, he worked exceedingly hard, and the result of his labours was apparent in the great success of the gathering.

The vote was unanimously passed.

Mr. JOHN GERRARD briefly responded, and said that he took the vote of thanks to include also the members of the Council and officers of the Society. Those gentlemen had done far more than he had done, and their services had been very willingly rendered.

The PRESIDENT (Mr. H. Bramall) said that the late Honorary Secretary, Mr. William Saint, had served the Society so faithfully that he had great pleasure in moving that the best thanks of the Society be given to Mr. Saint for his services.

Mr. JOSEPH DICKINSON said that he had very great pleasure in seconding the motion. Mr. W. Saint had been Honorary Secretary for about 10 years, and he had discharged the duties most faithfully and assiduously.

Mr. JOHN RIDYARD supported the motion, which was carried unanimously.

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DISCUSSION OF MESSRS. W. C. BLACKETT AND R. G. WARE'S PAPER ON "THE CONVEYOR-SYSTEM FOR FILLING AT THE COAL-FACE, AS PRACTISED IN GREAT BRITAIN AND AMERICA,"* AND MR. J. W. BATEY'S PAPER ON "THE MICKLEY CONVEYOR."†

The PRESIDENT (Mr. H. Bramall) said that the Mickley conveyor appeared to be very much like the old system that was in vogue before he came into the trade—a belt, chain and sled, to run across the face, and lead the coal into a skip at the end of the face. It seemed to be a revival of that system modernized, and made to suit present requirements. The other system, described by Messrs. Blackett and Ware, was an entirely new departure, so far as he knew, as the coal was conveyed across the face in a kind of trough, fitted with scrapers, instead of taking the wagon along the face. It did not appear to him that these methods would be valuable to miners in their immediate neighbourhood; but there were parts of Lancashire where thin mines were being worked, and some gentlemen from those parts would do well to investigate carefully what had been written and said about these conveyors, especially as to their suitability for this district. It appeared to him, that in a mine under 24 inches, or even under 30 inches, high, that some such system as those described might be usefully and economically worked in conjunction with mechanical coal-cutters or otherwise.

Mr. CHARLES PILKINGTON said that their mining engineer, Mr. P. L. Wood, had inspected the Mickley conveyor in operation in the north of England, where it seemed to be working very well; but it would be rather difficult to apply the system in their own mines. The conveyor could not easily be moved forward as the face advanced, and a very good floor and good roof were necessary. If they were working an exceedingly thin seam, with a long face, then he thought it would pay; but whether it would pay in their Lancashire workings he did not quite know. There was another means of conveying coal across the face that they had tried, which was not quite a success at first, but they were trying it again with a different arrangement. It was very

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 449; and vol. xxx., pages 116 and 278.

† *Ibid.*, 1905, vol. xxix., page 268; and vol. xxx., pages 118 and 278.

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much like the old chain-system, sliding the tub, boat-like along the coal-face, one rope being attached to two boats; and as one boat went down the other came up. It was uncertain whether it would be successful; but at present, it was out of use, because the face where it was tried was now stopped.

Mr. Joseph Dickinson said that when this paper was read before the Institution of Mining Engineers, he made a few observations upon it and called attention to the fact that the late Mr. Herbert Fletcher proposed a similar conveyor for one of the Atherton collieries, his idea being not only to convey the coal along the face of the workings but also to take it along the whole of the roadways and bring it up to the surface.

Mr. A. J. Tonge said that he had seen a Blackett conveyor working in a Yorkshire colliery, and he came away with the impression that it was quite suitable for seams with a fairly good roof, varying in height from 18 inches to 30 inches. He found that the difficulties of adapting the Blackett conveyor in a seam, 18 inches thick, would be of such a character that they could hardly be surmounted. He consequently adopted, at the Hulton colliery, a tub-system which answered well in a seam, 18 inches thick. They were now using six of these conveyor-tubs, running along the face for a distance of about 150 feet, and they had discontinued the intermediate drawing-roads. Instead of having drawing-roads about 42 feet apart, the main roads were now made about 150 feet apart. The results so far had proved very satisfactory. The wheels of the conveyor-tub were placed at the extreme ends, the box-portion being fixed in a low position; and, consequently, the tub ran almost close to the floor of the mine, and big lumps of coal could be rolled into the tub instead of having to be lifted. He did not think that it was necessary to go into the costs, but the system had been fairly satisfactory.

Mr. John Gerrard asked Mr. Tonge, with regard to the use of the Blackett conveyor, what was the least distance between the packs and the face that he considered would be required along the face, and within which the conveyor would work. He was told that it was necessary to have a width of not less than 13 feet, from the face, resting on timber. Apparently, this would be a difficulty, when working at a considerable depth, and with anything but a good roof.

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Mr. A. J. Tonge replied that the distance between the face and the pack-walls would not be far from 12 feet, at the particular time when the conveyor wanted moving. Ordinarily, the average distance would not exceed 6 feet; but he thought that it was possible to move the conveyor every shift, and, in that way, it might be possible to keep it within, say, 8 feet of the face. He found that, with the conveyor-tub, the packs could be kept within 8 or 9 feet of the face: this system was practically the same, as it required a straight line of face in the same way as the Blackett conveyor, and was moved systematically forward.

Mr. C. Pilkington remarked that timber could be set between the packs and the coal-face.

The President (Mr. H. Bramall) thought that Mr. Tonge's experience was likely to be that of most people working thin seams, namely that the Blackett conveyor would require too much room and be too troublesome to move; whereas the Mickley conveyor, the old-fashioned sled, could be easily moved. It was well worth the attention of those working mountain mines, who might enquire whether some modification of the Mickley conveyor could not be usefully applied. He did not think that it was a system likely to be useful generally in all mines; but it was evidently suitable for use in thin seams.

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The complete list of the Council for the ensuing year is as follows:—

President:

Mr. HENRY BRAMALL, M. Inst. C.E.

Vice-Presidents:

Mr. CHARLES PILKINGTON, J.P.

Mr. JOHN ASHWORTH, C.E. | Mr. D. H. F. MATHEWS, H.M.I.M.

Mr. GEO. B. HARRISON, H.M.I.M.

Vice-Presidents (*ex officio*):

Mr. JOSEPH DICKINSON, F.G.S.

Prof. W. BOYD DAWKINS, M.A., D.Sc., F.R.S., F.G.S.

Mr. R. CLIFFORD SMITH, F.G.S.

The Right Hon. the EARL OF CRAWFORD AND BALCARRES.

Lord SHUTTLEWORTH OF GAWTHORPE.

Mr. EDWARD PILKINGTON, J.P. | Mr. ROBERT WINSTANLEY, C.E.

Mr. HENRY HALL, I.S.O., H.M.I.M. | Mr. JOHN S. BURROWS, F.G.S.

Mr. WM. SAINT, H.M.I.M. | Mr. MARK STIRRUP, F.G.S.

Mr. WM. WATTS, F.G.S. | Mr. JOHN RIDYARD, F.G.S.

Mr. W. S. BARRETT, J.P.

Mr. G. C. GREENWELL, M. Inst. C.E., F.G.S.

Mr. JONATHAN BARNES, F.G.S.

Col. GEO. H. HOLLINGWORTH, F.G.S.

Mr. JOHN GERRARD, H.M.I.M.

Honorary Treasurer:

Col. GEO. H. HOLLINGWORTH, F.G.S.

Honorary Secretary:

Mr. SYDNEY A. SMITH, Assoc. M. Inst. C.E.

Other Members of the Council:

Mr. H. STANLEY ATHERTON. | Mr. VINCENT BRAMALL.

Mr. C. F. BOUCHIER. | Mr. W. OLLERENSHAW.

Mr. A. DURY MITTON, Assoc. M. Inst. C.E.

Mr. GEO. H. PEACE, M. Inst. C.E. | Mr. ALFRED J. TONGE, F.G.S.

Mr. WILLIAM PICKSTONE. | Mr. JESSE WALLWORK.

Mr. P. C. POPE. | Mr. L. B. WELLS, M. Inst. C.E.

Mr. GEORGE H. WINSTANLEY, F.G.S.

Honorary Auditors:

Mr. JONATHAN BARNES, F.G.S.

Mr. GEORGE H. WINSTANLEY, F.G.S.

Trustees:

Mr. JOSEPH DICKINSON, F.G.S.

Lieut.-Col. Sir LEES KNOWLES, BART., M.A., L.L.M., F.G.S., F.Z.S., D.L., M.P.

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New Honorary Members:

BOLTON, HERBERT. F.R.S.E. | STIRRUP, MARK, F.G.S.

New Members:

BASTOW, S. E.	HOOGHWINKEL, G. H. J.	SAIKE, YOSHIMA
BRAMALL, VINCENT	HORROBIN, WILLIAM	SCHOLES, T.
CARTER, JOSEPH	KNOWLES, R. E.	SETTLE, WILL
CASS, JOSEPH	LANDLESS, J. E.	SMITH, JOHN
COULSTON, P. B.	LORD, CHADWICK	SPEAKMAN, FRED.
DAWES, ALFRED	MORRISON, DANIEL	SPENCER, R. S.
GAMLEN, R. L.	MOUNTAIN, M. B.	STEWART, J. E.
GRANT, R. G.	PERCY, FRANK	TAKAGI, KÜCHIRO
GRAVE, J. U. ROGER	POWER, THOMAS	WALSHAW, JOHN
HARRIS, H. P.	PREECE, G. G. L.	WATERWORTH, JOS.
HARVEY, R. H.	RAMSDEN, C. S.	WHITWORTH, CHAS. S.
HODGE, W. GUY	RIGBY, H., B.Sc.	WILKINSON, H. TATLOCK
HOLLINGWORTH, F. H.	ROSS, ARTHUR	YOUNG, WILLIAM

New Associate Members:

BLACKWELL, G. G. | PRESTON, S. C.

ROSS, ARTHUR, F.I C., F.C.S.

New Associates:

WOODWARD, WILLIAM

New Students:

CRANKSHAW. HUGH M. | HARK, J. R. | TONG, F. N.

Members Deceased:

BANKS, THOS.	HOLDING, W.	JACKSON, C. G.
BOLTON, H. H.	HAWORTH, D.	MILLINGTON, W. W.

PEACE, GEORGE

Members Resigned:

DAVIES, G. M.	HOLLINGWORTH, DAVID	MORT, A.
HATTON, G. P.	MAKEPEACE, H. R.	NALL, SIMON

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MANCHESTER GEOLOGICAL AND MINING SOCIETY.

ORDINARY MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
NOVEMBER 14TH, 1905.

MR. HENRY BRAMALL, PRESIDENT, IN THE CHAIR.

The following gentleman was elected, having been previously nominated:—

HONORARY MEMBER—
Mr. WILLIAM SAINT, H.M. Inspector of Mines, Manchester.

The PRESIDENT (Mr. Henry Bramall) delivered his inaugural address, as follows:—

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PRESIDENTIAL ADDRESS.

By HENRY BRAMALL, M.Inst.C.E.

You will all agree with me, when I express regret that the great trade with which we are so intimately connected should be at present in so depressed a condition; and that the results of colliery-working are, from a financial point of view, so far from satisfactory. There are no doubt many causes which have contributed to this state of affairs. The selling price realized for our produce has fallen very seriously, and we find ourselves burdened with increased costs: such as the high rate of wages and the shorter hours worked; the burden of local taxation, which has been so largely increased of recent years; the further obligations imposed upon coal-owners by Parliament; and that misconceived tax which the present Government has laid upon our industry, a tax which I venture to think that neither the German, French nor United States Governments, nor indeed any Government who consider it part of their duty to encourage national industry, could ever have conceived. But the factor in these increased costs, to which I wish more particularly to direct your attention, is that concerned with wages; and my remarks have more especial reference to the South and East Lancashire district than to West Lancashire, as the two districts (prior to 1893) did not usually act in accord.

It will be in the recollection of most of you that there was a great boom in the coal trade, which began in the latter half of 1871 and continued through 1872 and 1873, while wages went up to a very high point. The boom was over and prices began to fall in 1874, and concurrently with them wages; and this fall continued until, in 1878, wages had been reduced to 10 per cent. below what is now known as "the standard of 1888." The lowest selling price was touched in 1880. In 1881, there was a slight revival, accompanied by advances in wages, until, in 1882, the point which has since been adopted as the datum-level or "the

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standard of 1888," was reached; and, at the latter end of 1882, wages were advanced 10 per cent. and so remained until 1885. The average selling prices, from 1881 to 1885, remained almost stationary, varying only 1d. or 2d. per ton on the average of the year, although there were the usual seasonal differences between summer and winter prices.

Wages, during the years 1885-1888, were reduced to the standard in summer and advanced 10 per cent. above the standard each winter.

Towards the end of 1888, a revival in the trade set in, and selling prices rose rather rapidly, reaching their highest point in 1890, when they were about 43 per cent. higher than in 1885. Successive advances in wages were also made, until, in 1890, they had attained to 40 per cent. above the standard of 1888. Prices then began to fall and continued to do so, although wages remained unaltered, until, in 1893, the pressure upon the colliery owners compelled them to seek relief, and an attempt to obtain a reduction in the rate of wages led to the great strike of 1893. The settlement of that strike was effected, as you will remember, by what is known as "the Rosebery conference," and its outcome was the establishment of the first Conciliation Board, which was empowered to regulate wages from August 1st, 1894, to August 1st, 1896; and a minimum rate of wages was agreed to of 30 per cent., and a maximum rate of 45 per cent., above the standard of 1888.

In August, 1894, wages were reduced 10 per cent., bringing them down to the minimum rate. Prices continued to fall during the years 1895-1897; and, although the first Conciliation Board, with its fixed minimum rate of wages, expired on August 1st, 1896, wages remained unaltered until October, 1898, when the second Conciliation Board was formed, and an advance of 2½ per cent. was conceded, bringing wages up to 32½ per cent. above the standard. This Conciliation Board, with the same maximum and minimum rates of wages as before, was to last two years from January 1st, 1899, to December 31st, 1900. About this time, a great revival occurred in the coal trade, and prices, in 1899, advanced rapidly until they attained their maximum in the last quarter of 1900.

The third Conciliation Board was formed to regulate wages from January 1st, 1901, to December 31st, 1903, with the same

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minimum rate of 30 per cent., but with an increase of the maximum to 60 per cent. This maximum rate of wages was attained on February 1st, 1901; but, by that time, prices had already begun to droop; they have since continuously fallen, and there have also been reductions in the rate of wages, which now stands at 40 per cent. above the standard of 1888.

The fourth and existing Conciliation Board was formed to regulate wages from January 1st, 1904, to December 31st, 1906; and the minimum rate was raised to 35 per cent. above the standard of 1888, the maximum rate remaining at 60 per cent.; so that wages are, now, only 5 per cent. above the minimum rate.

Plate IX. and Table I. shew that in the sixteen years since 1889 a higher range of wages has been paid than in the preceding sixteen years: during the sixteen years from 1874 to 1889 inclusive, the average rate of wages was 4 per cent. above the standard of 1888, whereas, for the sixteen years from 1890 to the end of the present year, the average rate of wages was 40 per cent. above the same standard.

TABLE I.—SHEWING THE VARIATIONS IN COLLIERS' WAGES IN RELATION TO THE BASIS OR STANDARD WAGES OF 1888.

Date of Change.	Character of Change.	Amount of Change.	Variations above or below the Basis or Standard Wages of 1888.	Date of Change.	Character of Change.	Amount of Change.	Variations above or below the Basis or Standard Wages of 1888.
		Per cent.	Per cent.			Per cent.	Per cent.
1874 May 1	Reduction	15	17½	1888 Nov. 1	Advance	5	10
1876 April 6	Do.	15	2½	1889 July 1	Do.	5	15
,, Aug. 1	Do.	7½	− 5	,, Oct. 1	Do.	5	20
1878 June 1	Do.	5	−10	1890 Jan. 1	Do.	10	30
1880 Dec. 1	Advance	5	− 5	,, Mar. 21	Do.	5	35
1881 April 6	Do.	5	0	,, Aug. 6	Do.	5	40
,, Aug. 1	Reduction	10	−10	1894 Aug. 1	Reduction	10	30
,, Nov. 1	Advance	10	0	1898 Oct. 5	Advance	2½	32½
1882 Nov. 1	Do.	10	10	1899 April 5	Do.	5	37½
1885 May 1	Reduction	10	0	,, Oct. 4	Do.	2½	40
,, Nov. 1	Advance	10	10	1900 Jan. 3	Do.	5	45
1886 June 1	Reduction	10	0	,, Oct. 3	Do.	5	50
,, Dec. 1	Advance	10	10	1901 Jan. 1	Do.	5	55
1887 May 1	Reduction	10	0	,, Feb. 1	Do.	5	60
1888 Jan. 1	Advance	10	10	1902 July 2	Reduction	10	50
,, April 2	Reduction	10	0	1903 Dec. 22	Do.	5	45
,, Oct. 1	Advance	5	5	1904 Aug. 16	Do.	5	40

There is another point of view from which this question of increased wages may be considered, and that is, the relation

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that wages bear to the total cost of production. If the average of five years' periods be taken, they shew that the percentage of the whole cost, which was paid directly in wages, was as follows:—1875-1879 inclusive, 66·25 per cent.; 1880-1884 inclusive, 66·26 per cent.; 1885-1889 inclusive, 67·79 per cent.; 1890-1894 inclusive, 70·74 per cent.; 1895-1899 inclusive, 70·74 per cent.; and 1900-1904 inclusive, 72·63 per cent. This shows that there has been an increase of about 6¼ per cent. in wages during the past thirty years.

The deduction which I draw from these figures is that we have got to face a permanently higher rate of wages in the future, and that labour will be an even more important item in the cost of production than it has hitherto been. We shall find it necessary to follow the example set by American engineers, and we shall have to economize labour, not by reducing the rate of wages paid to the men, but by utilizing to better advantage this costly labour; and by adopting any improvements, mechanical or otherwise, which will tend to reduce the amount of manual labour involved in the production of a ton of coal, and to render the labour, we employ, more efficient, and consequently more economical.

The consideration of the way in which this can be done opens up a wide field for study. The working of a mine is a very different matter from the working of a mill or a manufacturing establishment. The conditions in mines are constantly varying, and are at all times such as render difficult the adoption of any labour-saving appliances, except those of the simplest character. I purpose to glance briefly at one or two directions in which labour-economies may possibly be effected, and suggest a few points for your consideration.

The first thing that occurs to me is, that greater attention might be paid to proper organization, systematization and concentration. In some cases, especially in collieries which have been opened for some considerable time, the coal-getters are, more or less, scattered about the mine, entailing the maintenance of great lengths of roads, both for conveyance and air-roads, weakening the efficiency and increasing the cost of supervision. Economy may be effected by concentrating the men as much as possible, lessening the length of working-faces to be kept open

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and also the length of drawing-roads. Further, these roads should be so arranged that the conveyance-men (wagoners, jiggers, and so on) may be kept fully employed, and that they do not spend a large portion of their time in waiting for something to do. By diminishing the length of roads to be maintained, they can be kept in better order with fewer on-cost men or datalers, and by concentrating the miners they can be kept under better supervision. The firemen, not having to spend so much time in travelling from one place to another, will have more leisure to see that the working-faces and roads are kept in safe condition, that the colliers have a more regular supply of tubs, and that the whole routine of the mine is more systematically and regularly carried on.

It is generally admitted that the severest work of a collier is the holing and cutting of the coal, where it is at all hard, and it is a point well worth considering, how far mechanical coal-cutters can be introduced with advantage to supersede manual exertion. Some excellent practical papers on coal-cutters have been read before this Society; and papers recording further experience of their use in Lancashire mines, and especially setting forth how the difficulties in their application had been surmounted and the economical results were obtained, would be very welcome. Lancashire does not appear to be in the fore-front in the use of these machines, for, on reference to Mr. John Gerrard's report for the past year, I find that there are only 46 machines of all kinds in use in this district, and less than 220,000 tons of coal were got by them in 1904. Probably the difficulties with which we have to contend in this coal-field, such as bad roofs and floors, the steep inclination, and the disturbances and faults, together with the fact that in many of our mines the coal is moderately soft, may have a good deal to do with the slow progress of machine coal-cutting.

Several varieties of machine drills have been introduced, with economy of labour, and there may be room for the use of more of these handy little machines.

Heading machines, for cutting straight roads, have been of great service in some collieries in the Midlands. I may say, however, that I did not succeed with the one that I tried, the coal bursting off as soon as cut and repeatedly burying the machine.

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After the coal is cut and filled it requires hauling from the face to the pit-shaft; and, in this work, a very large amount of manual labour is employed. In this district, it appears, from the figures given by Mr. John Gerrard in his report, that about 17 per cent. of the total output is brought to the pit-shaft by manual labour; and, in what may be termed secondary haulage, that is, the bringing of the coal from the face to the main haulage, that about 67 per cent. is moved by men and horses. Is it not possible that a large amount of this manual and horse-labour might be dispensed with, and replaced by mechanical methods, with considerable economy? It seems to me that it might be so, especially when we remember that most collieries have now compressed-air plant available for the transmission of power into the innermost recesses of the mine. The adoption of small portable hauling-engines, wherever a lower-side place has to be worked, and so dispensing with the slow and laborious hand-crab winding, also tends to economy. We recently had a discussion on two systems of conveying coal across the face, which were said to give economical results, particularly in thin seams. It appears to me advisable to get mechanical haulage of some kind as near as practicable to the coal-face, and to dispense to the utmost possible extent with manual and horse-labour, and, so, get rid of that bone of contention "long drawing."

In the winding and handling of the coal on the pit-bank, automatic arrangements may result in some saving, by enabling a larger output of coal to be dealt with by fewer men. Creepers, conveyors, travelling belts, and endless ropes or chains are all useful, where material has to be moved; but judgment is required in adopting such appliances and it is only by system and organization that the adequate advantage can be gained by their use. In some cases, it is possible to economize labour in shunting railway-wagons by judicious arrangement of the sidings, so as to take advantage of gravity.

I do not mention any of the general economies in the working of collieries, as my object has only been to call attention to the wages question and to indicate some of the directions in which I think it possible that labour may be better utilized. We may venture to hope, too, that the more extended use of

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machinery will have the result of improving the lower class of workers in and about our mines, and providing us with a more intelligent race of workmen, whose faculties will be sharpened, and who will show a degree of perception and adaptability that will fully justify and compensate for the increased rate of wages that they will receive.

Mr. John Gerrard (H.M. Inspector of Mines) said that he was sure that the Society would have, during the coming year, the fullest benefit of Mr. Bramall's vast experience, and of the attractive influence which his presence in the chair would exercise upon the members generally. He (Mr. Gerrard) stated that, in his view, it was in the interests alike of the owner and the worker to furnish the men with the fullest opportunity of getting the greatest amount of coal; and if, by that means, the worker could obtain a large daily wage, the owner would also obtain a fair return on the capital invested. He moved that a hearty vote of thanks be given to the President for his address.

Mr. Robert Winstanley, in seconding the resolution, thought that it would be better to defer the discussion until the address was printed in the *Transactions*.

Mr. Joseph Dickinson, in supporting the resolution, remarked that the stirring address of Mr. Bramall, which applied to the every-day life of mining, one of the two objects of the Society, was a practical paper, and reminded him that Mr. John Knowles, when President of the Society, framed his address on similar lines. He (Mr. Dickinson) was happy to say that an improvement in the coal trade followed it, and he hoped that the same result would follow Mr. Bramall's address.

Mr. J. S. Burrows, in supporting the motion, thought that Mr. Bramall was on the right track. He had been trying to make the work of the coal-miner more comfortable and easier, and he had no hesitation in saying that such a policy would be beneficial to both masters and men. At present, a long time was occupied by the men in getting to their work, and often they had a good deal of uncomfortable travelling, so that much

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of their strength was gone before they began their day's toil. He (Mr. Burrows) was also endeavouring to improve the roads in the mine, so as to facilitate the men's work and to enable them to use their strength to the best advantage.

The resolution was heartily adopted.

The PRESIDENT (Mr. Henry Bramall), after expressing his thanks for the resolution, called attention to an alarmist statement in one of the Manchester newspapers to the effect that the large number of disused coal-pit shafts, scattered within the thickly populated parts of the city of Manchester, were a hidden source of danger. He deprecated the publication of these sensational statements, and thought that there was no substantial foundation for them.

Mr. JOSEPH DICKINSON, F.G.S., read the following short paper on "The Origin of Fossil Life":—

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THE ORIGIN OF FOSSIL LIFE.

By JOSEPH DICKINSON, F.G.S.

The origin of life generally has recently attracted attention. It has been lectured upon with effect by Mr. Butler Burke and Prof. Boyd Dawkins. The subject is wide and obscure. There is vegetable life, animal life, also the mineral kingdom with fossil remains.

This paper does not pretend entering upon the whole of the subject. Its aim is only to state briefly what is commonly admitted, that the species of fossil remains frequently varies in the different geological formations; and from this variation to infer that what caused the admitted change of fossil species in the formations, will be closely connected with the origin of all fossil life.

According to recognized stratification, the layers of rock in one geological formation differ from those in the adjoining formation, so as to be termed unconformable; the unconformability in some instances being such as to indicate deposition under a different centre of gravity.

The common kind of vegetable fossils often shew the original external impressions and occasionally what is taken to be the interior pith. The fossil shells, as found, are sometimes pure shell compressed in layers without interior body; others are complete with shell and body, the interior being stone. Some fossils constitute a nucleus, around which concretions of stone are formed. There are also concretions, or balls of ironstone, which contain a gelatinous substance.

The kind of bed or stratum in which fossils are found varies; sometimes it is soft and soon falls on exposure, and sometimes it is hard stone. Many of the most perfect remains are associated with limestone.

Among fossils, man nowhere seems to appear. There are waters having the property of petrifying certain substances into stone, and man thus petrified has been shewn. Man changed also into mummy has been found in peat bog. But not fossil man in natural rock.

A question might occur whether the assumed real fossils ever had life, or were only petrified forms. It would be extreme

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to assume so. Many geological worthies have testified otherwise, and innumerable complete fossil remains seem sufficient to forbid the supposition.

Assuming that the fossils once lived, how did the life originate? Life is associated with matter. Matter is convertible but indestructible. How did it begin? The combination, with renewed sustenance, continues for a time, each part influencing the other. If unhastened by ills, it terminates with age. It is an intricate problem to demonstrate.

The most ancient view of the beginning is the Mosaic narration, which is accepted by many as revelation and by some as Egyptian tradition. The order and accompaniments mentioned are: Creation, apparently with fossil life during ages; then stupendous divisions, followed by vegetation, fish, fowl, beast, and man formed from dust breathed into. Thus originated, the life seems typical man for mankind—otherwise, who were the assailants that Cain feared?

There is also the Frankenstein legend—a figure constructed so perfectly that it became a goblin imbued with life and played pranks with its constructor.

Now radium, with its peculiar property of heat, is suggested as the medium. Consideration of the whole subject seems to show that, whatever adjunct there may have been, life originated concurrently with extraordinary changes.

Limiting the consideration within the range of this paper, fossil species have evidently varied concurrently wth change of geological formation. This seems one step attained.

The further enlightenment has to be searched out. Be it through radium or something else, research such as that which discovered spectrum analysis and the atomic theory, may find this out also.

Prof. W. Boyd Dawkins said he was very glad indeed to find his old friend Mr. Dickinson had the same amount of scepticism, though from a different point of view, that he himself had as to the virtues of radium in discovering the origin of life. He must, Prof. Boyd Dawkins added, frankly say he was much surprised that in a matter of this kind, requiring accurate investigation and delicate experiments, there should have been such broad statements thrown before the public in Manchester with regard to the evolution of life through the presence of radium.

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The conditions of the experiments were unsatisfactory and the results are inadequate. Although he, himself, as was known, had not made a speciality of radium, when he looked at the results and found that they were exactly the same results as those which occurred in the ordinary lava as it passed from the fluid to the solid state, he, for one, was not prepared to accept the conclusion of Mr. Burke. He held that they were no nearer to the solution of the problem than they were when Prof. Huxley confessed himself baffled by it.

There was no evidence that hitherto anything had been found to bridge the interval between the inorganic and organic worlds.

The PRESIDENT (Mr. Henry Bramall) said it appeared to him that, so far as any actual knowledge of the source or origin of life was concerned, they were in about the same position as the ancients were thousands of years before the Christian era and they knew just as much about it as they did. Mr. Dickinson had referred to the Egyptian legend on which the Mosaic account of the creation of the world was no doubt founded, and he thought the authors of that account were baffled in their attempts to account for life and so they referred it to "the Spirit of God" which moved on the face of the waters. Did our present-day knowledge enable us to get any nearer the truth? He thought not.

FOSSILS AT BRADFORD COLLIERY, NEAR MANCHESTER.

Mr. JOHN GERRARD, H.M.I.M., exhibited specimens of fossils taken from the Marine bed at a depth of 692 yards in the Bradford colliery, Manchester. Two of the shells had been identified by Dr. Wheelton Hind and Mr. J. T. Stobbs as *Lingula* and *Bellerophon*. Mr. Gerrard remarked that in the Society's *Transactions* for 1862* reference was made to a Marine bed which was found in the vicinity of the river Tame, and which was further described in 1864; and later still, in 1880,† by Mr. George Wild, who had found that this Marine bed was passed through in the Ashton Moss sinking and was probably about 305 yards above the Roger seam.

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* "Marine Fossils at Dukinfield,' by Mr. Edward Hull, *Transactions of the Manchester Geological and Mining Society*, 1862, vol. iii., page 348; and 1863, vol. iv., page 69.

† "On Marine Fossil Shells at Ashton Moss Colliery Sinking, near Ashton under-Lyne," by Mr. George Wild, *Ibid.*, 1880, vol. xvi., page 37.

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MANCHESTER GEOLOGICAL AND MINING SOCIETY.

ORDINARY MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
DECEMBER 12TH, 1905.

MR. HENRY HALL IN THE CHAIR.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. JOSEPH KAY, Colliery Manager, Agecroft Collieries, near Manchester.

Mr. CECIL W. EAMES, Mining Engineer, Moss Hall Collieries, Platt Bridge, near Wigan.

STUDENT—

Mr. GEORGE ENTWISTLE, Mining Student, Birmingham University, Birmingham.

Mr. GERALD H. J. HOOGHWINKEL read the following paper on "The Generation of Electricity by the Waste Gases of Modern Coke-ovens":—

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THE GENERATION OF ELECTRICITY BY THE WASTE GASES OF MODERN COKE-OVENS.

By GERALD H. J. HOOGHWINKEL.

Introduction.—More and more ironmasters begin to understand and appreciate the immense waste of energy, which is still going on, day after day, in iron- and steel-works. As witness, the huge columns of flaming gases that one may see at night in the great iron and steel centres. Very slowly, indeed, is this growing conviction acted upon: everyone waiting to see his neighbour's results, and very few acting upon their own firm belief in new practices. A single case of bad results, caused by the inexperience of the makers of the (to them new) engines, is apt to cause a halt, and in the case of blast-furnace gas, has actually done so, setting back a growing industry for several years.

However, the application of blast-furnace gases to the production of power, and electrical power in particular, is an established fact in this country, the growth of which will be witnessed during the next decade, and will probably keep pace with the urgently-required remodelling and redesigning of iron- and steel-works in the near future.

Although the experiments of Mr. B. H. Thwaite in this country opened the way, the first large undertakings of this kind were established in Germany, and at present most of the iron-works in that country and in the United States are equipped with electric-power stations deriving their power from the gases of the blast-furnaces, while many of the powerful blower-engines are driven by the same agent.

The writer has had the good fortune to take part in the design and erection of some of the biggest and earliest undertakings, namely, the gas-plant at the Ilseder iron-works, supplying also the necessary power to the Peine rolling-mills, near Hanover. The entire steel-works and rolling-mills, at Peine, are driven by electricity generated from waste blast-furnace gases, a strik-

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ing example of the economy effected by modern practical applications.

But the same advantages, as regards the supply of power for driving the mechanical appliances of a modern coking-plant, with washing- and cleaning-plant near by, and even the plant at the pits, may be derived by using the surplus-gases from coke-ovens direct in gas-engines. The present method of burning the surplus-gases under old-fashioned boilers provides about 200,000 horsepower in the United Kingdom; and, if it be estimated that the direct burning of these gases in internal-combustion engines is three times as efficient, one may realize how much power that might be retained is now being wasted.

The question is one of public utility and economy, and the waste gases would provide this country with a source of cheap power, comparable to the water-power used in Canada and countries abroad. As cheap power is going to be the keystone of the existence of Great Britain as the oldest and first manufacturing country, the question is worth considering, even by men directly connected with collieries. Of course the quantities in question are not to be compared on the same lines, as blast-furnaces can supply a far greater quantity of gas for power-generation than coke-ovens. A modern blast-furnace, consuming about half the quantity of gas produced, may be expected to give about 20 horsepower per ton of pig-iron produced. Blast-furnace gas, however, is a poor gas, more like the gas obtained from modern producers, while coke-ovens produce a rich gas approaching town-gas. The importance of the power derived from coke-ovens for use at collieries may, therefore, be taken as being of the same value as the power derived from blast-furnaces for use in steel-works and rolling-mills.

Utilization of Coke-oven Gases for Power-generation.—Many, but still relatively few, coking collieries utilize the spare gases from their coke-ovens under steam-boilers, which supply steam to the auxiliary plant, and, sometimes, to continuous-running plant, namely, air-compressors and pumps. On account of their intermittent steam-consumption, it is often preferred to run winding-engines from separate coal-fired boilers.

The wasteful character of this method, as compared with the direct combustion of the gases in an internal-combustion

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engine, need not be insisted upon. To estimate the magnitude of this loss, one has only to remember that, of the quantity of coke produced in Great Britain in 1902 of 10,000,000 tons, only about 10 per cent. was produced in bye-product ovens. If it be assumed that most of these gases, after being freed of tar, ammonia and benzol, are passed under boilers, about 10 horse-power per oven will be obtained.

Modern bye-product ovens yield about 78 per cent. of coke on a charge of 4 tons of coal per oven. Using water-tube boilers, 1¼ pounds of water, on an average, can be evaporated per pound of coal coked in the ovens, where the bye-products are actually being recovered. As 30 to 40 hours elapse between each charge, about 11,000 pounds of steam are generated, and about 10 brake-horsepower per oven is produced.

When burned directly in a gas-engine, taking about 25 cubic feet of gas per brake-horsepower-hour, the amount of power per oven is about 25 brake-horsepower on the engine-shaft, or twice to three times as much as when burning the gases under steam-boilers. This estimate assumes that the coal produces 15,000 cubic feet of gas per ton of coal and that 25 per cent. of the gases are available for power-purposes. This calculation shows the great saving in power and, therefore, in coal (which is now burnt under boilers at collieries) to be derived from using the spare gases in gas-engines, even in comparison with the most up-to-date steam-plant. There are many collieries, on the Continent and in the United States, where coal is not burnt in a single boiler for power-requirements: including coke-ovens, washeries, air-compressors, winding-engines, pumping-engines, etc. This implies a saving in coal of 3 to 5 per cent. on the output, a figure which must be considered, now that most managers are coming back from the old and mistaken idea "that slack costs nothing at the pit-mouth."

Generally speaking, when introducing gas-engines, bye-product ovens will be required, and the saving in efficiency alone which these ovens represent over the old type of bee-hive oven, would amount to about £2,500,000 per annum in Great Britain. Add to this, the sale of bye-products worth about 4s. 6d. per ton of coal coked, and one may realize the savings that will be derived from the wholesale adoption of bye-product coke-ovens and gas-engines.

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Of course, all coals are not suitable for this coking process, as the quantity of spare gas is very variable. Many coals, with a small percentage of volatile matter, say, South Wales coals with 15 to 18 per cent., requiring a very high coking temperature, only give off enough gases to heat the walls of the coke-ovens and leave no surplus gases. Of course, by suitably heating the flues, or, better still, the air-supply (regenerative ovens), it is always possible to obtain a saving in gas of about 20 per cent. From good coking coal, such as Durham, Silkstone, etc., coal, with a percentage of volatile matter varying from 20 to 30 per cent., it is easy to utilize 20 to 40 per cent. of the total gas-production for power-purposes in gas-engines. Coals with a very high percentage of volatile matter, such as Durham gas-coals, need a very much higher temperature to produce a hard coke, and, therefore, do not leave more surplus gas than coal of a medium percentage.

Another important point, influencing the amount of surplus gas, is the quantity of water present in the coal; with washed coal, often containing over 15 per cent. of water, the amount of heat and, therefore, gas, required to evaporate this water, is very considerable.

It is quite possible, and even desirable, to combine both systems, and to pass the gases, which have been partly cleaned and freed from bye-products, after heating the flues and regenerators, under steam-boilers, while the surplus-gases are taken direct through additional cleaning-plant to the gas-engines.

There is, however, another direction in which the surplus-gases may be utilized, and in the United States there are many coking-plants, which supply neighbouring townships with gas for lighting purposes. The gases are carburetted with benzol, and compressed, in order to distribute them over distant districts, as the Mond-gas Company is doing in South Staffordshire. This, of course, eliminates the objection that there are no consumers near the coke-ovens requiring the surplus-gases for lighting purposes. One must not forget that the efficiency of these gases, when used for lighting, is about fifteen times as much as when burnt under steam-boilers, and this application is, therefore, worthy of consideration.

But by far the most important field for the utilization of spare gases is the direct driving of gas-engines. Roughly speaking, the writer has found, in many cases, that the cost

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per unit in coke-gas power-stations of medium size is about 0·1d. to 0·2d.

The production of cheap power at collieries is a question, gaining in importance every day, proportionately to the drop in the price of the saleable article and the increased depth of the pits. The firing of steam-boilers by means of small coal at the pit is an expensive method, and if no rubbish and refuse from the washeries are available, a very wasteful process, having regard to the low efficiency of the boilers. Even taking the value of this small coal at 2s. to 4s. per ton at the pit-mouth, the saving of coal by using gas-engines is a substantial item. Moreover, small coal and washed peas have a market value, nowadays; and it will not be long before a fuel will be made out of waste-heaps, which will, consequently, raise the commercial value of all small stuff at the pit-mouth. Every modern colliery should, therefore, either burn its rubbish and waste in gas-producers, or else compress and coke it in bye-product ovens, using the gases obtained in both processes for generating electrical power by means of gas-engines.

The Composition, Caloric Value, and Cleaning of Coke-oven Gases.—It may be useful to retrace, in a few words, the history of the blast-furnace gas-engine, the predecessor of the coke-oven gas-engine. The first experiments were carried out by Mr. B. H. Thwaite, but it seems that this investigation has not been duly followed up by engineers in this country, as they have allowed Germany to acquire a preponderant position in the gas-engine industry. During the last three years, more than 180,000 horsepower of blast-furnace gas-engines were erected in that country alone; and at the St. Louis Exhibition, a gas-engine was shewn with a capacity of nearly 2,000 horsepower in one cylinder, and of nearly 4,000 horsepower as a tandem engine.

The writer will record a few figures demonstrating the huge amount of power now being wasted. A modern blast-furnace produces per ton of pig-iron about 20 horsepower continuously, after allowing a loss of 10 per cent. during the charging of the furnace, and about 35 per cent. for heating the blast in Cowper stoves. Now, taking the annual pig-iron production at 20,000,000 tons. and allowing a saving of 3s. per ton of pig-iron,

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when utilizing blast-furnace gases, the importance of the introduction of gas-engines in iron- and steel-works may be gauged. This amount of power is not only available for driving blast-engines and furnace-lifts, but it may supply gas-engines driving rolling-mills and other plant in the steel-works, working on a very variable load. This has been recently shown at the Krupp works, at Essen, where some roughing-mills are directly driven by gas-engines.

Composition and Caloric Value of Coke-oven Gases.—The composition of coke-oven gases depends on several conditions and, moreover, changes considerably during the period of coking. Two of the most important of these conditions are the amount of moisture in the coal and the air-tightness of the coke-oven walls.

The changes in the composition of coke-oven gases, during coking, are shewn by the results of experiments made by Dr. F. Schniewind, at the works of the United Coke and Gas Company, Glassport, Pennsylvania.* An analysis of the gases, taken between the exhaust-fan and the scrubbers, was as follows:—I. First 15 hours: hydrogen, 38·4 per cent.; marsh gas, 38·7 per cent.; carbon monoxide, 6·1 per cent.; hydrocarbon gases, 5·2 per cent.; carbon dioxide, 3·6 per cent.; oxygen, 0·3 per cent.; and nitrogen, 7·7 per cent. II. Last 19 hours: hydrogen, 50·5 per cent.; marsh gas, 29·2 per cent.; carbon monoxide, 6·3 per cent.; hydrocarbon gases, 2·4 per cent.; carbon dioxide, 2·2 per cent.; oxygen, 0·3 per cent.; and nitrogen, 9·1 per cent.

The gradual variations in the composition of the gas may be seen in Fig. 1.† The hydrogen curve rises in the last half of the coking process, while the marsh-gas curve falls. This shows a higher illuminating-power for all the gases generated during the first period. The rise of the nitrogen curve is probably due to the entrance of air through cracks in the ovens. Fig. 2‡ represents graphically the calorific value, specific gravity and candle-power of the gases tested in Dr. Schniewind's experiments.

An analysis of the gases from coke-ovens at the Consolidation colliery, in Westphalia, yields the following results:—Hydrogen,

* *Trans. Inst. M. E.*, 1901, vol. xxii., page 619.

† *Ibid.*, page 641. ‡ *Ibid.*, page 642.

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48·9 per cent.; marsh gas, 35·8 per cent.; carbon monoxide, 7·2 per cent.; hydrocarbon gases, 3·2 per cent.; carbon dioxide, 1·2 per cent.; and nitrogen, 3·7 per cent. These results were obtained by retort-sampling, and are slightly different from those obtained in actual practice: the retort being perfectly air-tight, the amount of nitrogen is much smaller. From the point of view

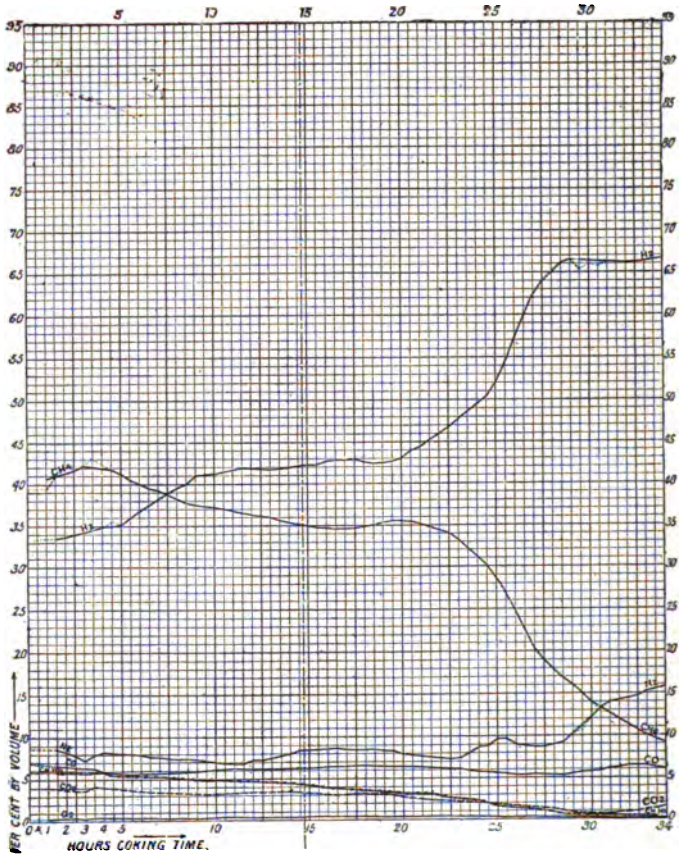

FIG. 1.—ANALYSES OF COAL-GASES PRODUCED FROM OTTO-HOFFMANN COKE-OVENS.

of the value of the bye-products, the amount of nitrogen is important, as affecting the yield of ammonia. It is, however, of no use in a gas-engine, as it reduces the heating-power of the gases.

Another good example from modern Otto coke-ovens, with the latest improvements, is furnished by a sampling of the

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gases from the Mathias Stinnes colliery, in Westphalia, where gas-engines of over 1,500 horsepower were erected in 1901. The coal-charge of the ovens was washed, and the amount of water was therefore considerable; and, as this process will be followed more and more with modern bye-product ovens, the sampling may be taken as representing modern British practice as well,

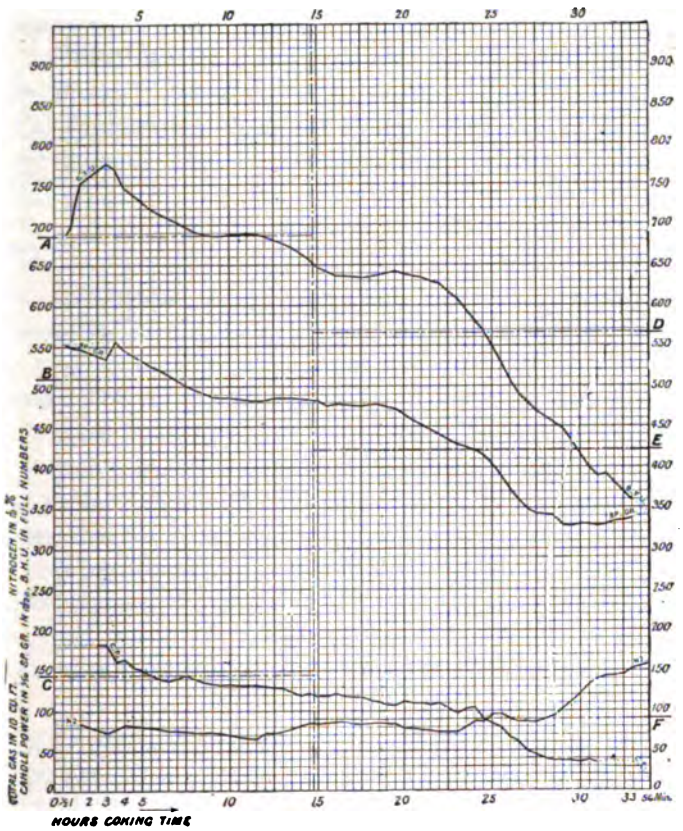

FIG. 2.—CALORIFIC VALUE, SPECIFIC GRAVITY AND CANDLEPOWER OF COAL-GASES PRODUCED FROM OTTO-HOFFMANN COKE-OVENS.

the coal being equal to best British coking coal. The coal contained 15½ per cent. of volatile matter and 7½ per cent. of ash; and it produced 75 per cent. of coke, 4 per cent. of tar, and 1½ per cent. of ammonia. The average composition of the gases was found to be as follows:—Hydrogen, 45 per cent.; marsh gas, 30 per cent.; carbon monoxide, 10 per cent.; carbon dioxide,

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2·5 per cent.; hydrocarbon gases, 2·5 per cent.; and nitrogen, 10 per cent. The temperature in the oven-flues was 1,900° to 2,250° Fahr.

The result of these samplings has shown that the composition, and therefore the caloric value, of the gases varies considerably during the coking process. Of course, the number of ovens in operation tends to equalize these figures, as may be seen from Fig. 3 recording the variation of calorific value during one day, in a battery of 60 Potter coke-ovens at a British colliery. The importance of keeping the value of the gases constant will be appreciated by everyone used to the large gas-engines in blast-furnace works, and various means have been adopted for this purpose.

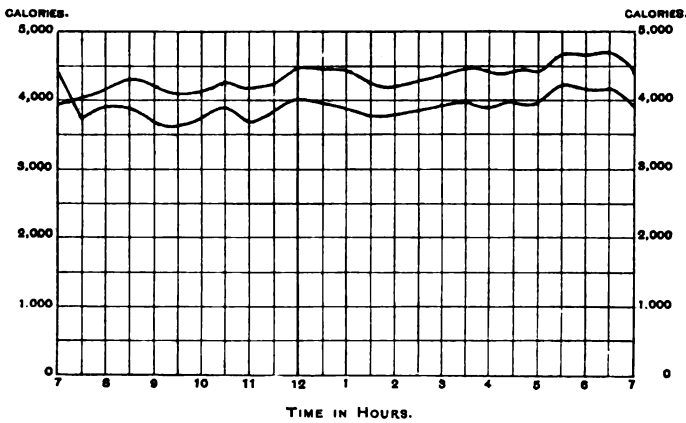

FIG. 3.—CALORIFIC VALUE FOR ONE DAY OF COAL-GASES PRODUCED FROM POTTER COKE-OVENS.

At the Mathias Stinnes colliery, two gas-mains were connected to each oven, one being the rich gas-main for the gas-engines, and the other the poor gas-main for heating the ovens and boilers. Other collieries mix the coking coal and take great care in always measuring the correct charge. A gas-tank of ample dimensions is, of course, the best guarantee of keeping the calorific value constant. The quantities and calorific values of the gases depend on the quality of the coal, the amount of moisture and the type of oven. Table I. records the results at five large coke-oven gas-plants, the figures giving the average results of everyday practice.

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TABLE I.—ANALYSES OF SPARE GASES FROM COKE-OVENS.

Name of Colliery ..	Stumm.	Julien.	Borsig.	Theresien.	Johannis.
Type of Oven	30 Under-flue.	300 Otto.	76 Regenerative	120 Regenerative.	
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Hydrogen, H ...	43·9	35·2 to 40·8	42·0 to 48·1	27·0 to 46·0	40·1
Marsh gas, CH_4 ...	26·6	18·6 ,, 19·0	18·4 ,, 20·3	14·0 ,, 29·0	22·8
Carbon monoxide CO	7·0	12·6 ,, 13·4	10·2 ,, 11·8	4·0 ,, 5·2	9·0
Heavy hydrocarbon gases	3·0	0·4 ,, 1·4	1·8 ,, 2·6	1·0 ,, 2·0	1·6
Carbon dioxide, CO_2	3·5	2·3 ,, 4·0	4·9 ,, 5·3	4·2 ,, 5·0	5·7
Oxygen, O ...	0·3	1·0 ,, 1·2	0·2 ,, 0·4	0·3 ,, 1·2	0·6
Nitrogen, N ...	15·4	26·3 ,, 26·6	15·9 ,, 18·7	30·0 ,, 40·0	20·2
Sulphur, S ..	—	—	—	0·20	—
Calorific value in British thermal units	480 to 560	320 to 412	412	340 to 360	390

The amount of power to be derived from a battery of 80 ovens of a modern type, coking a charge of 7 tons in 32 hours, using coal of a medium percentage of volatile matter, giving off about 7,000 cubic feet of gas per ton per hour, or in all 122,500 cubic feet per hour, would, therefore, be as follows:—If the ovens used 70 per cent. of the gases for heating the flues, then there should remain about 36,000 cubic feet for power, and, taking a consumption of 25 cubic feet per indicated horsepower, about 1,500 indicated horsepower should be available, or nearly 20 indicated horsepower per oven. This amount varies, of course, with the coal and type of oven, and the writer knows of cases where the power was nearly 30 indicated horsepower per oven.

The Cleaning of Coke-oven Gas.—The purification of the gases is of primary importance, and nothing should be neglected to arrive at the highest degree of purity. Most of the early failures in blast-furnace and coke-oven gas-plants were traceable to imperfect cleaning: perfect cleaning not being thought necessary. Tar and ammonia are condensed with comparative ease and so too the naphthaline (benzol) and cyanogen; but the dust in connection with the remaining quantities of tar should be most carefully removed.

After varied and lengthy experiments, the writer has come to the conclusion that the correct method is to purify all the gases from dust, including the gases used in the gas-engines,

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and the gases used for heating the oven-flues and the boilers. The higher calorific value of the purified gas ensures higher temperature in the flues and better coking, and also saves gas. The purified gas does not cover the oven-flues and boilers with a coating that demands repeated cleaning. Another condition is the elimination of water-vapour. The gases from the ovens contain from 5 to 15 per cent. of water-vapour, especially if the charge consists of washed coal. This water has the effect of rendering the gas difficult to burn. At the same time, the temperature must be lowered from 280° to about 60° Fahr. Water-sprayed fans and quickly-revolving washers on the Theissen principle are too expensive, and require too much power to drive them; and, moreover, the water is brought into contact with the hot gases, and charges the latter with a further quantity of water-vapour.

A complete revolution in these methods was produced by the introduction of the slowly revolving washer. The apparatus is giving most excellent results at blast-furnace gas-plants, and the writer is of opinion (based on experiments) that its introduction into all coke-oven plants is highly desirable, even if no gas-engines are installed. It is cheap, highly efficient, and requires much less water than other appliances. The gases are cooled from 550° to 400° down to 86° Fahr. in certain cases, at the same time losing their water-vapour by condensation. The main purpose is, of course, the elimination of dust, and consequent better utilization of the ovens and boilers.

The further gas-cleaning plant depends on the particular methods of extracting the bye-products used at each coking-plant; and, therefore, no general rule can be laid down for the apparatus required.

The tar and ammonia are extracted in a row of condensers using water and air as a cooling medium; and, afterwards, in washers and scrubbers of different construction. The washers and scrubbers may be combined with dust-extracting and additional cleaning plant. The extraction of tar is, of course, dependent on the state in which the tar is present in the gases (whether in fine spray or otherwise), and this largely depends on the cooling arrangements. The danger of leaving tar in the gases cannot be exaggerated; and sticky valves, pre-ignition and sooty cylinders are such highly undesirable features that it is easy to understand

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the importance of evading them. To do this at once, after the gases leave the ovens, and at the same time to do away with the presence of steam due to the moisture present in the coal and to the cooling water, is the object of the rotary washer.

As rotary washers are likely to supersede all the present arrangements for cooling and purifying coke-oven and blast-furnace gases, a short description of the Bian washer may be of interest. In a metal cylindrical shell, a number of wire-gauze discs revolve slowly on a horizontal axle, immersed up to their centre in flowing water. The hot gases enter at the front side and are confronted with the wire-gauze discs, containing thin films of water in the meshes; these water-films are evaporated at once, and the gases give off some of their latent heat. This process is repeated until the gases are not hot enough to evaporate more water, and then the films act as condensers and condense the vapour present in the gas. At the same time, the greater part of the impurities are precipitated, and the gases are cooled and ready for further cleaning. The gases even become richer, as part of the carbon dioxide is dissolved in the water, while the greater part of the water-vapour, present in the gas as it comes from the ovens, is eliminated. The fans used for the additional cleaning may therefore be much smaller, and absorb less power than when used on the hot gases.

Bian washers are now installed in various works in Germany and Belgium, etc., and have been entirely successful, using about 40 horsepower, including the driving of the ventilator or fan and cleaning 40,000 cubic feet of gases per minute in one apparatus. For a battery of, say, 50 modern retort-ovens, this would mean about 15 horsepower. The cooling reached in most installations is up to 60° Fahr. At this temperature it is comparatively easy to extract the remaining tar-spray before the gases enter the ammonia and benzol separator: a simple coke-scrubber being perfectly sufficient.

Tar.—The essential conditions for extracting the tar are gradual and efficient cooling, combined with some kind of wet and dry cleaning.

The initial cooling and dry cleaning in air-coolers or condensers is generally considered to render the wet cleaning by means of a Theissen or, better still, a Bian or Holmes washer,

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more effective. They are cheap, and require no power or supervision, as they simply consist of a number of U tubes standing on a horizontal receiver, half filled with tar. Between the two legs of each tube is a plate with its end in the tar, so as to force the gases through the tubes; sometimes the receiver is divided in two, and the gases only pass through one pair of tubes. The latter arrangement provides for the passage of more gas in the same apparatus. The coolers reduce the temperature of the gases from about 550° Fahr. to 170° Fahr., and cost about 3s. per square foot of cooling surface. They may be arranged in parallel or in series, and any combination to suit requirements can easily be effected.

FIG. 4.—PELOUZE-ADOUIN TAR-SEPARATOR.

The most up-to-date plants have a revolving gas-washer, of any of the abovementioned makes, directly connected to the air-cooling plant; the temperature is further reduced from 170° down to 70° or 60° Fahr. In addition to and in consequence of the cooling effect, the tar and dust are for the greater part eliminated.

Directly after the washer come gas-fans, Root blowers, exhausters or turbine-exhausters, which give the necessary velocity through the cleaning and bye-product plant. The temperature of the gases being much lower, these fans or ventilators can be used of much smaller dimensions than formerly, when they were installed directly after the air-cooling plant.

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Bye-product Plant.—The gases now enter the bye-product plant, which comprizes: (1) A tar-separator, of some kind; (2) an ammonia-washer; (3) a benzol-washer; (4) a cyanogen-washer; (5) a hydrogen-sulphide washer; and the necessary stills, separators and tanks for the manufacture of sulphate of ammonia, commercial tar and pitch, light oils, benzine, etc.

(1) The tar-separator generally consists of one or more coke or sawdust scrubbers, but in the older plants a Pelouze-Adouin (Fig. 4) or other special tar-separator is used. At present, the latest practise is to use the Bian or Theissen washer, with tar as a washing and cooling medium, to remove the last traces of sooty tar.

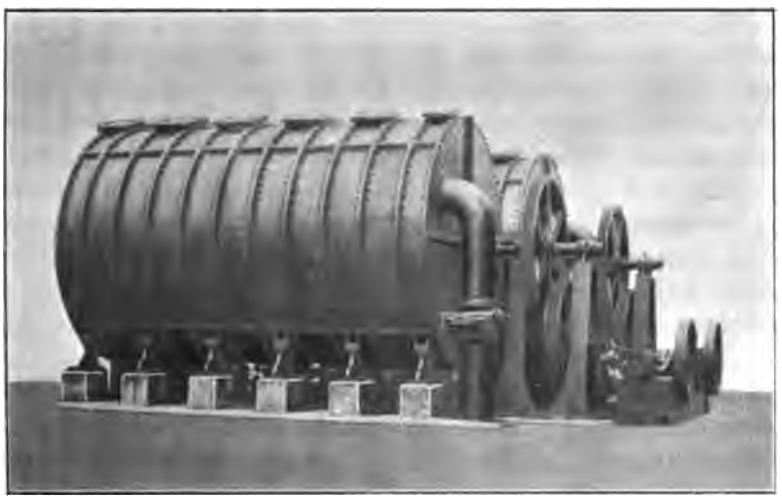

FIG. 5.—HOLMES ROTATING GAS-WASHER.

(2) The ammonia-washer either consists of one of the many scrubbers (of which the Zschocke scrubber is far the best) or of a rotary washer of the Holmes or Zschocke type. Zschocke scrubbers require about 2 gallons of cooling water per 1,000 cubic feet of gases, and leave only about 5 grains of ammonia (NH_3) per 1,000 cubic feet of cleaned gas. The Holmes rotating-washer (Fig. 5) is one of the slowly-revolving type (1 revolution per minute), and consists of a cylindrical drum with brushes revolving on a horizontal axle. The Zschocke washer has a revolving part, consisting of wooden balls with holes fixed in a

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disc-holder. Both types have several compartments connected by tubes, and water is supplied in a direction opposed to the flow of the gases. Owing to the slow rotating movement, the power-consumption is very small. These appliances extract nearly all the ammonia, leaving only 2½ grains per 1,000 cubic feet. The washing-water may be either pure water or liquor, and may be used over and over again, until a solution of sufficient strength is obtained.

(3) The benzol or naphthalene is extracted by the same class of apparatus as the ammonia, the washing medium being tar-oil.

(4) The cleansing for sulphur and cyanogen is not generally considered necessary. Most of the German coke-works, however, have adopted some sort of cleaning plant, and the writer certainly agrees with this policy. The valves, and especially the spindles, may or may not be attacked by the acids which are formed by the oxidation of the hydrogen sulphide in the cylinders. The protection, however, of the costly gas-engine plant is of such primary importance, and, if any doubt exists, the removal of both sulphur and cyanogen should be insisted upon by the makers of the gas-engine, as cyanogen attacks the pipes and cylinders, and reduces the heating value of the gas. Of course, much depends on the composition of the coal and the amount of sulphur contained therein, and it must not be forgotten that most of the sulphur remains in the coke.

Several types of dry scrubbers, sometimes in combination with a revolving washer, have been used for this purpose in different German works. These appliances are rather costly and create a certain nuisance, as the active matter (in this case iron-ore and sawdust or wood-wool) has to be renewed very often. It is, however, possible to use it over and over again (ten times) by regenerating it in the open air. Moreover, the saturated iron-ore is a marketable product, as it can be used for the production of cyanogen.

Dry scrubbers have, however, another duty to perform: the final removal of the last traces of tar and water, and the tar-oils used in the benzine-washers.

In works where sulphur-troubles are not to be feared, one may see dry scrubbers being used for a final cleaning, containing layers of iron-ore and of wood-wool. They must be cleaned every 8 or 10 weeks. Recently slag-wool has been used, with satisfactory results, as a scrubbing agent.

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The most up-to-date and cheapest sulphur-extracting plant is erected at the Mathias Stinnes colliery. A revolving cleaner of the Bian type is used to extract the sulphur and cyanogen by mixing fine hydroxide of iron in the water, whereby sulphide of iron is formed, and it may again be regenerated by blowing air under pressure through the cleaner. It is also a marketable commodity which can be sold to sulphuric-acid manufacturers.

It is not intended to describe the various stills and tank arrangement used for the distillation and the manufacture of saleable bye-products, such as tar, pitch, sulphate of ammonia, benzol, tar-oils, etc.

The control and constant pressure of the gases may be ensured, by a speed-regulation apparatus placed in front of the fans or turbine-exhausters. It is an equalizer, regulating the equilibrium of the gases between the exhaust and pressure sides, by means of a diving-bell balanced by a counter-weight. The movements of the bell are communicated to a double-acting valve, which establishes communication between the exhaust and pressure sides.

In order to ensure the thorough mixture of the gases from the ovens in different stages of the coking process, a gas-holder of reasonable dimensions is of great advantage. An hour's supply should be provided for, with about 20 cubic feet capacity per horsepower installed.

Gas-engines.—The scope of this paper does not admit of a complete treatment of the coke-oven gas-engine and the different types and makers. The large gas-engine industry is still in its infancy, to use a commonplace expression, but although there are now several good systems, and each system has its particular advantage, it is the expert's work to distinguish and to adopt the correct engine in each particular case, depending on the gases available, their degree of purity, and many other particulars (Table II.).

The principal theoretical grouping consists in dividing gas-engines into four-cycle and two-cycle engines. The particular features of each kind are so well known that it should be sufficient to enumerate shortly the advantages and drawbacks of each type, at the same time giving some particulars of the different makes. The large gas-engine is far more difficult to

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construct than a large steam-engine, and the technical difficulties may be said to increase with the size. The correct choice of the materials to be used, and the particular construction of the working parts owing to the enormous stresses and temperatures, are difficult problems, which it took reputed makers many years to solve. At present, therefore, only first-class makers with well-established records of engines of the same size should be considered.

TABLE II.—LIST OF RECENT INSTALLATIONS OF COKE-OVEN GAS-ENGINES.

Name of Works.	Type of Gas-engine.	Total Power Employed.	Number of Gas-engines.	Capacity of each Gas-engine.
		Horsepower		Horsepower.
Withomitz Colliery ...	Berlin-Anhalt: four-cycle, with four cylinders	900	3	300
Graf-Lärisch Colliery: Karwin	Berlin-Marienfelde: four-cylinders, single-acting	700	1	700
Carolinen Colliery ..	Cockerill: four-cycle, single-acting	250	1	250
Yorkshire Iron and Coal Company, Tingly	Cockerill: four-cycle	500	2	250
Gross Wolkte Colliery ..	Koerting: two-cycle, with two cylinders	500	1	500
Julien Iron-works ..	,, ,,	1,200	4	300
Messel Colliery	,, ,,	1,000	2	500
Neunkirchen Coke-works: Stumm	Nürnberg: single-acting	200	1	200
Burbach Iron-works and Coke-works	Nürnberg: double-acting	1,200	1	1,200
Consolidation Colliery .	,, ,,	160	1	160
,, ,, ..	,, ,,	1,360	2	680
Constantin Colliery: Bochum	,, ,,	1,200	1	1,200
Eschweil Colliery ...	,, ,,	1,000	2	500
,, ,, ..	,, ,,	1,100	1	1,100
Gelsenkirchen Colliery ...	,, ,,	500	1	500
Lothring Colliery ...	,, ,,	350	1	350
Minister Stein Colliery ...	,, ,,	550	1	550
Shamrock Colliery	,, ,,	800	1	800
Stumm Colliery	,, ,,	1,000	1	1,000
Anna Colliery	Oechelhauser: two-cycle, with two cylinders	550	1	550
Borsig	,, ,,	600	1	600
Cargo Fleet Iron-works ...	Premier	1,000	2	500

The ordinary four-cycle or Otto engine has the advantages of simplicity and high efficiency, and it occupies comparatively small floor-space; it has, of course, only one impulse in four strokes, and is, therefore, not very suitable to be coupled to three-phase generators, which have to work in parallel.

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In order to reduce the size of single-cylinder engines, engines of over 200 horsepower are built, with two or four cylinders, either side by side or in tandem. The latter arrangement has the advantage of less loss through friction, as there is only half the bearing-surface and one flywheel and crank. Large engines, of 1,200 horsepower and more, are usually built with four cylinders, arranged as a double-tandem engine. Although a step in the right direction, the two and four-cylindered single-acting engine still has several drawbacks. The engine is bulky, and therefore heavy and costly; it shows an increased oil-con-

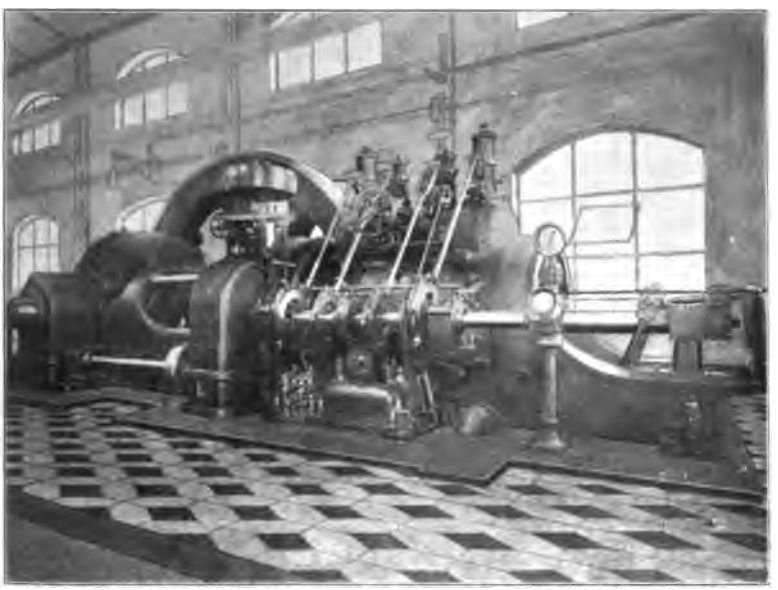

FIG. 6.—NÜRNBERG SINGLE-CYLINDER DOUBLE-ACTING COKE-OVEN GAS-ENGINE, OF 500 HORSEPOWER, AT GELSENKIRCHEN COLLIERY.

sumption, and therefore high-running costs; and it requires considerable floor-space.

In order to combine the advantages of the multi-cylinder engine (regularity, smaller cylinders, and all round less bulky dimensions), the double-acting engine was brought out, thus again following steam-engine practice. In this way, the full advantages of the two-cycle engine are obtained, while retaining the simple construction of the four-cycle engine. The best-known engine of this type gives about double the power for the

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same dimensions. It has one small disadvantage, the use of stuffing-boxes, which, however, it has in common with the tandem-engine.

The best known large four-cycle gas-engines built to use coke-oven gas are the Nürnberg, the Deutz, the Koerting, the Berlin-Anhalt, the Danek, and the Cockerill. Each of these wellknown engines have, of course, their particular advantages, though the Nürnberg engine has been perhaps the most popular. The very high efficiency of this engine is due to the double acting, two

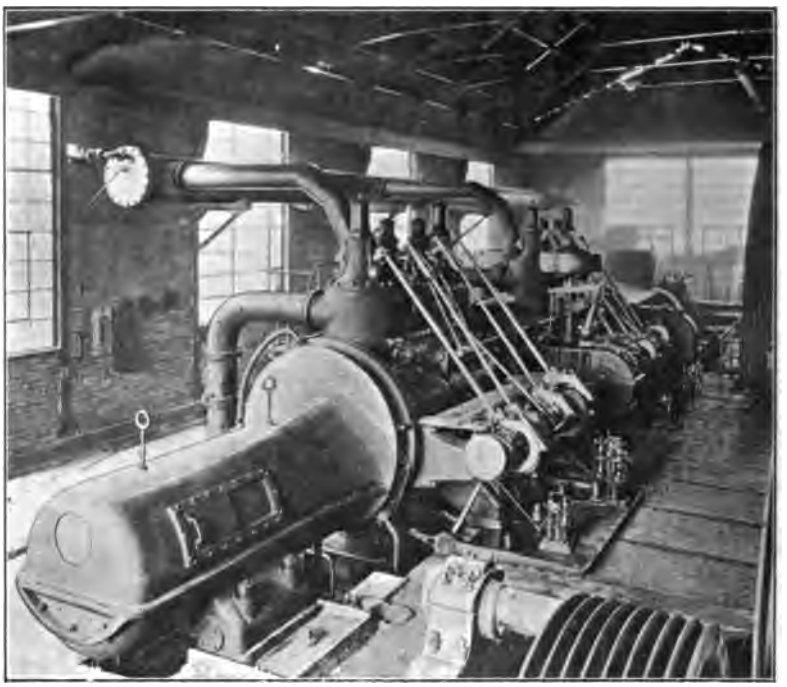

FIG. 7.—NÜRNBERG TWO-CYLINDER DOUBLE-ACTING COKE-OVEN GAS-ENGINE, OF 1,000 HORSEPOWER, AT STUMM COLLIERY.

or four-cylindered tandem arrangement, giving the advantages of great regularity and reasonable dimensions of the two-cycle engine, while retaining in full the simplicity and high thermal efficiency (28 to 39 per cent.) of the four-cycle engine. In addition, the engine is extremely easy to dismantle, in order to clean the valves and cylinders, an advantage which will be appreciated at coke-oven and blast-furnace works where the gases for some reason or another are not sufficiently clean and

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free from tar or dust. Figs. 6, 7 and 8 show recent installations at coke-oven works abroad where Nürnberg gas-engines of large capacity have been installed.

A short description of a typical large coke-oven gas-engine of the Nürnberg type may be of interest. The cast-steel bed-plate extends the full length of the engine, it acts as a guide for the crosshead, carries the main bearings, and it acts as an oil-sink for the oil-lubrication of the cranks. The action of the gas-engine being downward, there is only one guide-

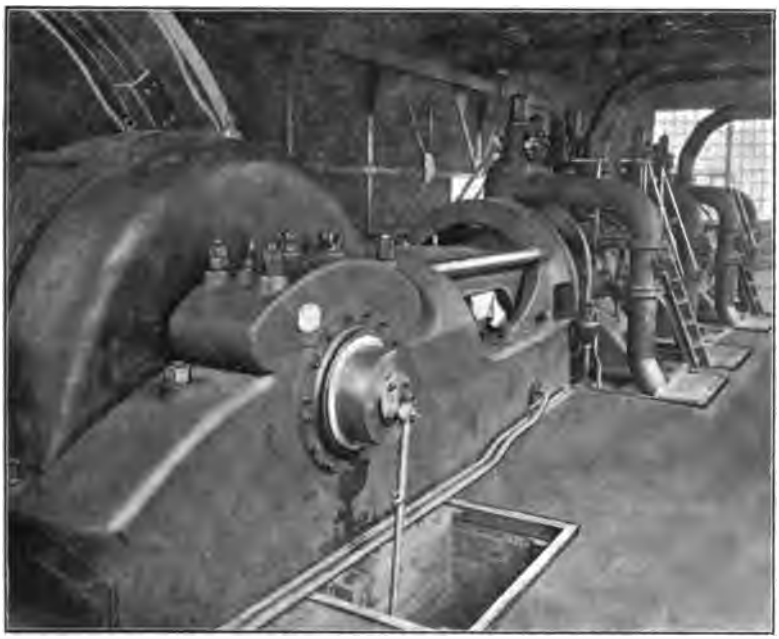

FIG. 8.—NÜRNBERG TWO-CYLINDER DOUBLE-ACTING COKE-OVEN GAS-ENGINE, OF 1,100 HORSEPOWER, AT ESCHWEIL COLLIERY.

lining. The symmetrically-shaped cylinders are made of cast-iron, which material responds better to the variations due to excessive heat. The cylinders are water-jacketted all round, including the ends and heads. The valve-chests, where the gas and air are mixed, are screwed to the cylinders; they are also water-cooled. A distance-piece carries the guide between the cylinders. The water-cooled pistons are carried on specially hollow cast-steel rods, which also act as cooling-water supply-pipes. They are short, and are fitted with cast-iron rings. The

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crossheads are made of nickel-steel, and slide on the white-metal lining of the guides. The construction of the connecting-rod renders it quite possible to extract the piston without dismantling the crosshead and guides. The crank-shaft, made of Siemens-Martin steel, revolves in two bearings lined with white-metal. Forced lubrication is supplied by a small oil-pump, and there is a separate one for each stuffing-box. The inlet-valves have an independent circular slide-valve fixed to the stem; they are actuated by roller-path levers, eccentrics and ratchet-movements fixed on one shaft. The governor acts directly on the stroke of the inlet-valves, and is driven by the valve-gear shaft. The air and gas are mixed in the double gas-valve, and enter the cylinder through the inlet-valve. The exhaust-valve, which is pressed on its seat by the explosion, is water-cooled, as is also the exhaust-valve chest. The cooling-water is further compressed by a small pump, and flows through the different water-jackets into a common drain-pipe, which conveys it to the cooling-tower or other water-saving apparatus. The quantity of water required is about 6 gallons at 60° Fahr. per brake-horsepower-hour, and if cooling-towers are used the water required to make up the loss is about 0·4 gallon per brake-horsepower-hour.

The two-cycle engine is represented by the Cockerill, the Koerting, and the Oechelhauser engines, which have been extensively used at blast-furnace and coke-oven works in Germany. Their chief advantage is the regularity which is ensured by having one impulse every two strokes, instead of every four strokes. The double-acting, two-cycle Koerting engine, as well as all other Koerting engines, is provided with a special mixing-valve, regulating the simultaneous passage of the air and gas before admission into the cylinder. The automatic valves are lifted by the suction only, falling back by their own weight as soon as the inlet-valve closes through compression. The inlet-valves, operated by cams, are situated at each end of the cylinder, while the exhaust-ports are placed in the centre. The gas and air are supplied by separate pumps, which first deliver pure air and then a mixture of uniform composition, the quantity of which regulates the power of the engine. The pressure exerted by the pumps is about 15 pounds per square inch (Figs. 9 and 10).

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The Oechelhauser engine is in so far the simplest, as there are no valves, and the mixture introduced by the pumps is compressed between two pistons in one cylinder. The gas and air are supplied by one pump, in line with the engine, and actuated by the back-piston rod. The pistons, themselves, form slide-valves, and the engine is single-acting. Notwithstanding a certain complication due to the various connecting-rods and the use of three

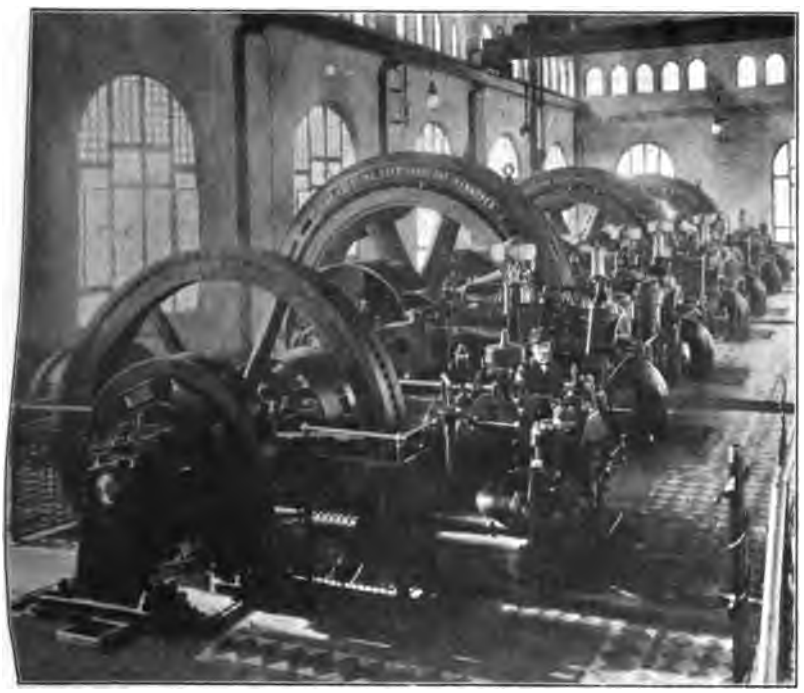

FIG. 9.—FOUR KOERTING TWO-CYCLE, SINGLE-CYLINDER DOUBLE-ACTING COKE-OVEN GAS-ENGINES, OF 300 HORSEPOWER, AT JULIEN IRON-WORKS.

cranks, this arrangement ensures simplicity and a perfect balancing of the working parts, and especially of the crank-shaft, neutralizing the reactions of the bearings. The disadvantages are the great length (although the pump can be arranged under the engine) and the great weight and dimensions of the single-acting type, and a somewhat lower efficiency, which the engine has in common with all two-cycle engines fitted with separate pumps. Also, it appears to the writer that the small

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pump-cylinders and valves are not exactly the place for the possible accumulations of dust which take place in the cylinders of the four-cycle engine. The net efficiency of the two-cycle engine is about 75 to 80 per cent. while 90 to 92 per cent. is reached by the four-cycle engine.

In double-acting four-cycle engines, of which the Nürnberg is the best type, the thermal efficiency varies from 28 to 30

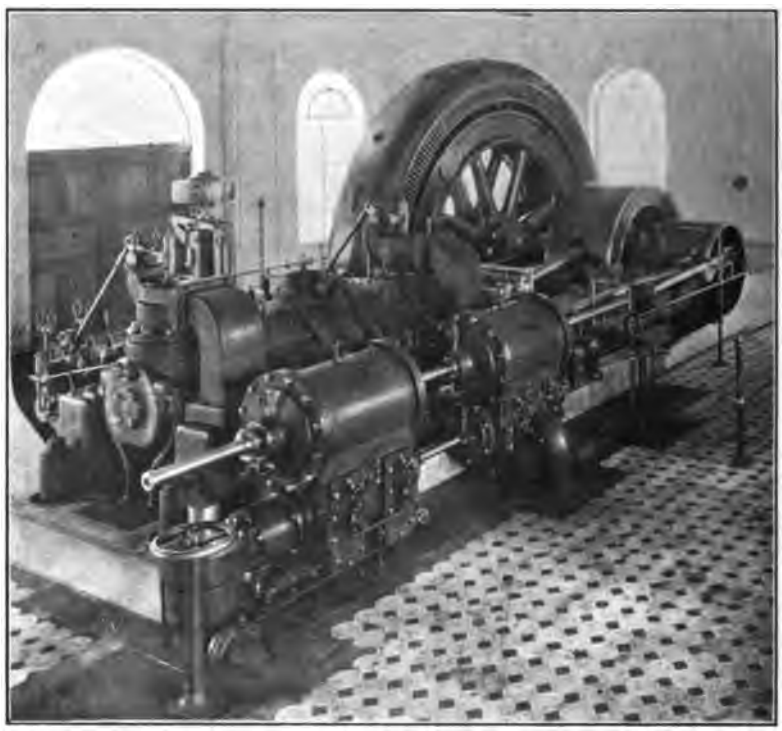

FIG. 10.—KOERTING TWO-CYCLE, SINGLE-CYLINDER DOUBLE-ACTING COKE-OVEN GAS-ENGINE, OF 500 HORSEPOWER, AT MESSEL COLLIERY.

per cent. of effective work, and about 20 cubic feet of coke-oven gas per horsepower. The weight is now about 200 pounds per horsepower. For use with coke-oven gases, where the efficiency is more important than with blast-furnace gases, four-cycle engines of the Nürnberg type are decidedly to be recommended.

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Mr. Gerald H. J. Hooghwinkel said that he advocated the erection of coke-ovens or gas-producers at every colliery, not because the owners wanted to make coke; but in order to get rid of an enormous amount of dirt and waste, which should be coked, and the coke-oven plant should be used as a gas-producer. For, after all, a coke-oven plant was in a way a huge gas-producing plant, and the best way of getting rid of this waste-material was to put it into gas-producers or coke-ovens, instead of wasting and storing it at the colliery. If coke-ovens were used as gas-producers sufficient gas would be made to work all the plant of the colliery with it. As a secondary product, there would be the coke, which at some collieries would be good furnace-coke; and at others, it would be sold for household purposes, etc. The gas would be the principal product, and the coke should be considered as a bye-product. In some towns in the United States, coke-ovens had been erected instead of ordinary gas-retorts, and the gas was sold for lighting purposes only.

The Chairman (Mr. Henry Hall) said that the writer implied that there should be coke-ovens at every colliery, and that the gas should be drawn from the coke-ovens and sent to the boilers or gas-engines direct. He thought that it would be difficult to establish coke-ovens at all collieries, because there were really very few collieries producing coal that would make coke at all. There were very few coke-ovens in the Lancashire district: the reason being that the coal is not suitable. A long time ago, when he (Mr. Hall) was manager of a colliery, the idea was mooted that the gases from the coke-ovens should be utilized; and one or two schemes were tried of collecting some of the gases and applying them under steam-boilers. But the result always seemed to be that, so soon as the ovens were modified in this way, complaints came from the iron-works that the coke was inferior to that which had been sent previously, and ultimately it really meant that if the gas was utilized the general value of the coke was reduced. That was an important point in the proposed scheme; and, in fact, it was the real reason why the utilization of these gases had not become more general. Coke for sale must be of good quality, and the colliery-owner could not afford to injure it in any way. He (Mr. H. Hall) had pleasure in moving a vote of thanks to Mr. Hooghwinkel for his paper.

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Mr. W. H. JOHNSON, in seconding the proposal, remarked that no doubt gas-engines had a great future before them, and everything that would tend to bring that future nearer would be acceptable to the members.

The motion was carried unanimously.

Mr. GEORGE ELCE described the way in which the coke-and-gas question was dealt with at the colliery with which he was connected. As the gas obtained was not sufficient for lighting purposes, it was used for heating the ovens themselves, and after the gas had been burned in flues round the ovens, it was passed under the boilers in a somewhat old-fashioned way. The gas produced at the coke-ovens would never be able to run an electric plant, but it sufficed to run the bye-product pumps. He thought that the prejudice against retort-coke, mentioned by the chairman, because the gas had been collected from it, had been overcome and did not now exist.

Mr. A. DURY MITTON agreed with Mr. Hall that there were many coal-seams in Lancashire quite unfit for coking. He had experimented on the coal from a large number of them and found that the density, as also the percentage of volatile matter or of ash, was the main cause. He did not think that Mr. Hooghwinkel's suggestion was practicable, namely, to erect coke-ovens simply for the bye-products, and to leave the coke as a waste-product, when unsaleable. The price and market for small coal for the mills in Lancashire was a feature in coke-making, which had to be carefully considered in comparison with other coal-fields. He thought that, if proper care was taken and the latest appliances were used, retort-oven coke would hold its own in any market against the product obtained from the bee-hive coke-oven.

Mr. R. L. GAMLEN remarked that a Koerting gas-engine of 2,000 horsepower covered a space 55 feet 9 inches long and 50 feet broad, while a Curtis turbine, of the same capacity, was only 10 feet square. The gas-engine covered a floor-space of 2,700 square feet, whereas a steam-turbine of the same horsepower covered only 100 square feet; and, in the same way, a gas-engine of the above-mentioned size weighed 340 tons against 35 tons in the case of a turbine, or practically ten times as much. He thought that the cost of the buildings and founda-

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tions to cover and support the various types of engines must be, of necessity, highly in favour of the smaller plant. Before the erection of the plant of the Lancashire Power Company was commenced he spent some time in journeying through Great Britain examining many cases of driving by gas-engines, and he came to the conclusion that, at present, at any rate, there was not sufficient reliable experience to warrant the adoption of this class of drive; and time had only confirmed his opinion on that point.

He knew of an order for two gas-engines of 700 horsepower that was given nearly three years ago, and he believed that they were just starting to turn round. The delay in getting to work had been entirely due to the unsatisfactory performance of the plant and the overcoming of experimental difficulties. If it had been necessary to spend all this time in experimentation in order to bring a small plant, with engines of 700 horsepower, to a fit state of work, it was conceivable that as many more years might have to pass before a plant of 2,000 horsepower could be made to work satisfactorily.

There was now an extremely satisfactory method of disposing of very dirty coal, other than by burning it in a producer, namely, by dust-firing. There had been in the past great difficulty in utilizing coal-dust as fuel, as the combustion-chamber had invariably melted away in the very fierce heat. Now, however, carborundum-lined fire-bricks were used, which would stand an enormous temperature. In one case, where the calorific value of the fuel was about 10,000 British thermal units, the percentage of carbon dioxide was uniformly as high as 15, shewing very perfect combustion. The bye-product was liquid slag and dust, both of which were far more easily handled than ordinary slag from a furnace of whatever type.

Mr. W. H. Coleman described a method by which coke-oven gas could be cleansed from impurities, and said any plan that tended to economy in the use of coal was worthy of the attention of the members.

Mr. Gerald H. J. Hooghwinkel stated that nearly all coal could be made into coke, if it was sufficiently mixed in different quantities and qualities, crushed and the charge compressed. The only economical and profitable way of dealing with the

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rubbish was to put it into coke-ovens or into gas-producers. Burning it under boilers was a most wasteful process, unless it was properly treated by washing or pulverizing. If there was no demand for coke, the use of gas-producers was preferable; but, if there were a sufficient demand for coke, coke-ovens should be erected. It was an error to suppose that the quality of the coke was injured if the gas was extracted from it. He did not think that the extraction of the bye-products did any harm to the coke; and, on the contrary, he believed that the coke was better for their extraction. The slack and waste, valued at 3s. to 4s. per ton in Lancashire, could be utilized far better in the production of coke and electric power.

The steam-turbine was no doubt the ideal steam-engine, and the Curtis turbines at the power-station of the Lancashire Power Company required very little ground-space. The large area of 2,700 square feet was mentioned as being required for a gas-engine of 1,000 horsepower; but, as a matter of fact, a Nürnberg gas-engine of 1,000 horsepower only required an area of 400 square feet.

The advantage of the introduction of the flexible electric agent between the gas-engine and the mining plant, instead of direct driving by the gas-engine, was too evident to be seriously disputed.

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The entire Series of the Geological Survey Maps on the o... and six-inch scale, with Memoirs, of the Lancashire Coal Field, is complete, and available for reference by the Members.

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PART VI. VOL. XXIX.

TRANSACTIONS

OF THE

MANCHESTER GEOLOGICAL & MINING SOCIETY.

EDITED BY

THE HONORARY SECRETARY.

SESSION 1905-1906.

PUBLISHED AT THE ROOMS OF THE SOCIETY,
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THE INSTITUTION OF MINING ENGINEERS.

SIXTEENTH ANNUAL GENERAL MEETING,

HELD IN THE TOWN HALL, MANCHESTER, SEPTEMBER 13TH, 1905.

MR. H. C. PEAKE, PAST-PRESIDENT AND CHAIRMAN OF COUNCIL, IN THE CHAIR.

ELECTION OF OFFICERS, 1905-1906.

The SECRETARY announced the election of officers for the ensuing year by the Council as follows:—

PRESIDENT:
SIR LEES KNOWLES, BART.

VICE-PRESIDENTS:

MR. WILLIAM ARMSTRONG.	MR. A. H. HEATH.	MR. R. T. MOORE.
MR. T. W. BENSON.	MR. W. B. M. JACKSON.	MR. H. B. NASH.
MR. H. BRAMALL.	MR. GEORGE MAY.	MR. W. G. PHILLIPS.
MR. JOHN DAGLISH.	MR. R. MCLAREN.	MR. J. G. WEEKS.
MR. J. T. FORGIE.	MR. T. W. H. MITCHELL.	MR. R. S. WILLIAMSON.

AUDITORS:
MESSRS. JOHN G. BENSON AND SONS, Newcastle-upon-Tyne.

TREASURERS:
MESSRS. LAMBTON & COMPANY, The Bank, Newcastle-upon-Tyne.

Mr. JOHN GERRARD moved a vote of thanks to the retiring Vice-Presidents, Councillors and officers for their services during the past year.

Mr. S. F. WALKER seconded the resolution, which was cordially approved.

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DISCUSSION OF MR. A. R. SAWYER'S PAPER ON "THE SOUTH RAND GOLD-FIELD, TRANSVAAL."*

Mr. A. R. SAWYER (Johannesburg, South Africa) wrote that the references to Figs. 2 and 3, Plate XXV., and Fig. 4, Plate XXVI.,† should be modified as follows:—

Lower Karroo: Ecca Beds, with a Coal-seam.
Dolerite.
Dwyka Conglomerate or Breccia, below Ecca Bed.

DISCUSSION OF MR. F. HIRD'S PAPER ON "THE ELECTRICAL DRIVING OF WINDING-GEARS: SUPPLEMENTARY NOTE."‡

Mr. W. C. MOUNTAIN (Newcastle-upon-Tyne) wrote that the following corrections should be made in his remarks§ upon this paper:—Line 3, "when accelerated" should read "during acceleration"; line 16, "it was more economical" should read "it was generally more economical"; and line 20, "an engine winding at the rate of 120 feet per second" should read "an engine winding at the speed of about 70 feet per second."

The SECRETARY read the Annual Report of the Council as follows:—

* *Trans. Inst. M. E.*, 1904, vol. xxvii., page 546.
† *Ibid.*, page 554.
‡ *Ibid.*, 1903, vol. xxv., page 592; and vol. xxix., page 392.
§ *Ibid.*, vol. xxix., page 396.

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SIXTEENTH ANNUAL REPORT OF THE COUNCIL.

It is the painful duty of the Council to report the death of their esteemed President and colleague, Sir Lowthian Bell, Bart., one of the founders of the Institution, who presided at the initial meeting held in London on June 6th, 1888. They have conveyed to Sir Hugh Bell, Bart., and the family of Sir Lowthian Bell an expression of their deep regret at the irreparable loss which they have sustained, and of their sincere sympathy with them in their bereavement. It is impossible to estimate the value of the services that Sir Lowthian Bell rendered to The Institution of Mining Engineers, in promoting its objects and in devoting his time and energies to its advancement.

The following table exhibits the progress of the membership since the formation of the Institution in 1889:—

Year ending July 31st.	No. of Honorary Members.	No. of Members.	No. of Non-federated.	Totals.
1890	0	1,189	50	1,239
1891	0	1,187	9	1,196
1892	14	1,401	19	1,434
1893	14	1,519	19	1,552
1894	13	2,055	123	2,191
1895	13	2,197	109	2,319
1896	13	2,288	81	2,382
1897	13	2,434	60	2,507
1898	13	2,449	47	2,509
1899	15	2,430	41	2,486
1900	15	2,432	35	2,482
1901	15	2,509	30	2,554
1902	15	2,556	30	2,601
1903	17	2,645	26	2,688
1904	17	2,742	22	2,781
1905	16	2,944	74	3,034

The societies constituting The Institution of Mining Engineers have been increased, during the year just ended, to seven, by the adhesion of the Manchester Geological and Mining Society, this society having joined the Institution from August 1st, 1904. The Institution now comprizes the Manchester Geological and Mining Society; the Midland Counties Institution of Engineers;

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the Midland Institute of Mining, Civil and Mechanical Engineers; the Mining Institute of Scotland; the North of England Institute of Mining and Mechanical Engineers; the North Staffordshire Institute of Mining and Mechanical Engineers; and the South Staffordshire and Warwickshire Institute of Mining Engineers.

The Annual General Meeting of the Institution was held in Birmingham, on September 14th, 15th and 16th, 1904. The London Meeting was held on June 1st, 2nd and 3rd, 1905. Both of these meetings secured the attendance of a considerable number of members, and the papers communicated were of an interesting character. The thanks of the Institution have been sent to the owners of collieries, works, etc., which were thrown open to the members attending these meetings.

Prizes have been awarded to the writers of the following papers, which are printed in the *Transactions* (vols. xxvi. and xxvii.):—

"The Occurrence, Mode of Working, and Treatment of the Ironstones found in the North Staffordshire Coal-field." By Mr. John Cadman.

"The Action, Influence and Control of the Roof in Longwall Working." By Mr. H. W. G. Halbaum, M.Inst.M.E.

"Underground Temperatures, especially in Coal-mines." By Prof. Hans Hoefer.

"The Dynamics of the Winding-engine." By Mr. S. L. Thacker, M.Inst. M.E.

"Electric Coal-cutting." By Mr. W. Walker.

"The Re-tubbing of the Middle Pit, Murton Colliery, 1903." By Mr. W. O. Wood, M.Inst.M.E.

Addresses have been delivered during the year by Mr. John Gerrard, President of the Manchester Geological and Mining Society; by Mr. T. W. H. Mitchell, President of the Midland Institute of Mining, Civil and Mechanical Engineers; by Dr. Robert Thomas Moore, President of the Mining Institute of Scotland; by Mr. A. H. Heath, President of the North Staffordshire Institute of Mining and Mechanical Engineers; and by Prof. R. A. S. Redmayne, President of the South Staffordshire and Warwickshire Institute of Mining Engineers.

The papers comprized in the *Transactions* during the past year have been of an interesting and varied character, and the high standard of the *Transactions* has been well maintained.

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The papers on geology include the following:—

"Notes on the Crow's Nest Coal-field, British Columbia." By Mr. James Ashworth.

"The Hunter V. Mine, British Columbia." By Mr. James Ashworth.

"*Prestwichia anthrax* and *Belinurus lunatus* from Sparth Bottoms, Rochdale." By Mr. Walter Baldwin.

"Sparth Bottoms Quarry, Rochdale." By Mr. Walter Baldwin.

"A Section of the Glacial Deposits met with in the Construction of the New Docks at Salford." By Prof. W. Boyd Dawkins.

"The Permian and Carboniferous Rocks in a Section in High Street, Chorlton-on-Medlock, Manchester." By Prof. W. Boyd Dawkins.

"Note on a Natural Paraffin found in the Ladysmith Pit, Whitehaven Collieries." By Mr. R. Dodds.

"The Cullinan Diamond." By Dr. G. A. F. Molengraaff.

"The Northern Portion of the Bristol Coal-field." By Mr. J. T. Onions.

"Coal-mining in Borneo." By Mr. James Roden

"The Coal-fields of Cape Colony." By Mr. Archibald Russell.

"The Geology of Chunies Poort, Transvaal." By Mr. Arthur Robert Sawyer.

"Gold-mining in Southern Rhodesia." By Mr. Thomas Warth.

"Notes on Coal in the Transvaal." By Mr. John J. Whitehead.

Mining engineering has been the subject of the following papers:—

"Goaf-blasts in Mines in the Giridih Coal-field, Bengal, India." By Mr. Thomas Adamson.

"Systematic Timbering at Emley Moor Collieries." By Mr. Hiram Baddiley.

"The Action, Influence and Control of the Roof in Longwall Working." By Mr. J. T. Beard.

"A Method of Packing Excavations in Coal-seams by Means of Water." By Mr. E. O. Forster Brown.

"Mountain Tunnelling." By Mr. Joseph Dickinson.

"Tapping and Running-off a Head of Water from a Shaft." By Mr. John Fox.

"Problems of Working Thick Coal in Deep Mines." By Mr. Laurence Holland.

"Coal-mining in Asturias, Spain." By Prof. Henry Louis.

"An Inburst of Waste-water at Wallyford Colliery." By Dr. Robert Thomas Moore.

"The Use of Cement-concrete in the Working of Thick Coal-seams." By Mr. Joseph Hippolyte Piffaut.

"The Action, Influence and Control of the Roof in Longwall Working." By Mr. Edward Heton Roberton.

"Coal-mining in Borneo." By Mr. James Roden.

"Notes on the Principal Gold-mining Districts and Mines of Western Australia." By Mr. W. T. Saunders.

"Description of Houldsworth Colliery, Dalmellington." By Mr. William Smith.

"The Bengal Coal-fields, and some Methods of Pillar-working in Bengal, India." By Mr. George A. Stonier.

"Gold-mining in Southern Rhodesia." By Mr. Thomas Warth.

"Notes on Coal in the Transvaal." By Mr. John J. Whitehead.

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The following papers have been contributed on mechanical engineering:—

"The Hunter V. Mine, British Columbia." By Mr. James Ashworth.
"The Automatic Prevention of Overwinding of Hoisting, Winding and Haulage-engines or Motors." By Mr. J. S. Barnes.
"Safety-catch for Cages." By Mr. Joseph Clegg.
"Winding of Minerals from Inclined Shafts." By Mr. Robert Crawford.
"The Electrical Driving of Winding-gears: Supplementary Note." By Mr. F. Hird.
"Electric Pumping at Collieries." By Mr. Gerald H. J. Hooghwinkel.
"The Compound Winding-engine at Lumpsey Mine." By Mr. Matthew Robson Kirby.
"Electric Winding-engines at the Exhibition of the North of France, Arras, Pas-de-Calais." By Mr. Ed. Lozé.
"Pneumatic Coal-boring Machines and Tools." By Mr. W. Lynch.
"Notes on Capels for Winding-ropes." By Mr. T. W. H. Mitchell.
"The Problem of Dynamic Balance." By Mr. Edward Heton Roberton.
"The Circulation of Water in Steam-boilers." By Mr. Arthur Ross.
"Notes on the Principal Gold-mining Districts and Mines of Western Australia." By Mr. W. T. Saunders.
"A Colliery Plant: its Economy and Waste." By Mr. A. J. Tonge.
"Fire in a Lanarkshire Colliery, and Description of a Condenser used thereat." By Mr. James C. Weir.
"A Safety-brake for Hand-cranes." By Mr. G. J. Williams.

The applications of electricity have been discussed in the following papers:—

"The Automatic Prevention of Overwinding of Hoisting, Winding and Haulage-engines or Motors." By Mr. J. S. Barnes.
"Notes on the Application of Electric Power at Mines in Germany." By Mr. E. O. Forster Brown.
"Notes and Considerations on Systems having Work of an Intermittent and Irregular Character to Perform: Methods of Lead-compensation." By Mr. Maurice Georgi.
"The Electrical Driving of Winding-gears: Supplementary Note." By Mr. F. Hird.
"An Outbreak of Fire, and its Cause, at Littleburn Colliery." By Mr. M. F. Holliday.
"Electric Pumping at Collieries." By Mr. Gerald H. J. Hooghwinkel.
"Electric Winding-engines at the Exhibition of the North of France, Arras, Pas-de-Calais." By Mr. Ed. Lozé.
"A Colliery Plant: its Economy and Waste." By Mr. A. J. Tonge.
"An Electric Indicating Two-wire Signal." By Mr. J. Willis.
"A Fatality caused by Low-pressure Electric Current in a Lancashire Colliery." By Mr. George H. Winstanley.

Mine-surveying instruments have been discussed in the following paper:—

"Mine-surveying Instruments: Part II." By Mr. Dunbar D. Scott.

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The education of mining engineers has been discussed in the following papers:—

"The Education of Mining Engineers in the United States." By Prof. Howard Eckfeldt.
"An Outline of Mining Education in New Zealand." By Prof. James Park.
"The Mining Department of the University of Birmingham." By Prof. R. A. S. Redmayne.
"The Development of Higher Education in North Staffordshire." By Prof Thomas Turner.

Ankylostomiasis has been discussed in the following papers:—

"The Miners' Worm-disease as seen in Westphalian and Hungarian Collieries." By Dr. Thomas Oliver.
"The Effect of the Watering of Coal-mines on the Spread of Ankylostomiasis." By Mr. Jonathan Wroe.

Dust and its treatment has been the subject of the following papers:—

"Observations on Water-sprayed or Damped Air in Coal-mines." By Mr. James Ashworth.
"Outbursts of Gas and Coal at the Morrissey Collieries, British Columbia." By Mr. James Ashworth.
"An Improved Watering-tub for Laying Dust in Coal-mines." By Mr. Henry Lawrence.
"The Dust-danger." By Mr. W. H. Pickering.
"An Improved Apparatus for Laying Dust in Coal-mines." By Mr. J. Cresswell-Roscamp.
"The Effect of the Watering of Coal-mines on the Spread of Ankylostomiasis." By Mr. Jonathan Wroe.

The occurrence of fires and rescue-appliances have been described in the following papers:—

"The Problem of Gob-fires." By Mr. George Farmer.
"The Work of a Joint Colliery Rescue-station." By Mr. M. H. Habershon.
"An Outbreak of Fire, and its Cause, at Littleburn Colliery." By Mr. M. F. Holliday.
"The Occurrence of Underground Fires at the Greta Colliery, New South Wales." By Mr. Joshua Jeffries.
"Fire in a Lanarkshire Colliery, and Description of a Condenser used thereat." By Mr. James C. Weir.

The recent history of explosives is set forth in the following paper:—

"The Development of Explosives for Coal-mines." By Mr. Donald M. D Stuart.

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The utilization of the waste-heat of coke-ovens is described in the following papers:—

"The Firing of Babcock and other Boilers by Waste-heat from Coke-ovens." By Mr. T. Y. Greener.

"The Utilization of Surplus-gases from Bye-product Coke-ovens." By Messrs. G. Blake Walker and L. T. O Shea.

The application of conveyors in mines is the subject of two papers:—

"The Mickley Conveyor." By Mr. J. W. Batey.

"The Conveyor-system for Filling at the Coal-face, as Practised in Great Britain and America." By Messrs. W. C. Blackett and R. G. Ware.

The miscellaneous papers comprize:—

"Underground Horses at an Indian Colliery." By Mr. Thomas Adamson.

"Barometer, Thermometer, etc., Readings for the Year 1904." By Mr. M. Walton Brown.

"Note on a Natural Paraffin found in the Ladysmith Pit, Whitehaven Collieries." By Mr. R. Dodds.

"Note on the Composition of Coal from the Faröe Islands." By Mr. R. Dodds.

"The Taxation of Collieries." By Mr. Arthur Hassam.

"Notes on Safety-lamp Oils." By Dr. G. P. Lishman.

"Hennebique Ferro-concrete Construction." By Mr. S. S. Platt.

"Note on the Calorific Effect of Coal from the Faröe Islands." By Mr. R. R. Thompson.

"Note on the Composition of Dover Coal." By Mr. R. R. Thompson.

The preceding list, comprizing 80 papers, demonstrates the varied nature of the subjects dealt with in the *Transactions* (vols. xxviii. and xxix.). During the past year, "Notes of Papers (236) on the Working of Mines, Metallurgy, etc., from the Transactions of Colonial and Foreign Societies and Colonial and Foreign Publications" have been continued, and should prove of value to the members.

The report of the Council on the Coal-mines Regulation Act (1887) Amendment Act, 1903, and its effect upon the qualifications of candidates for certificates of competency, has been printed in the *Transactions*.

The Rev. G. M. Capell represented the Institution at the meeting of the Corresponding Societies of the British Association for the Advancement of Science, held at Cambridge on August 18th and 23rd, 1904.

The Institution of Civil Engineers have appointed a special committee to consider the education and training of engineers, and Prof. Henry Louis has been nominated to serve on the committee on behalf of this Institution.

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An International Congress of Mining, Metallurgy, Engineering and Applied Geology was held at Liége, from June 25th to July 2nd, 1905, in conjunction with the Universal Exposition held in that city. The Council nominated Mr. H. C. Peake, Past-President and Chairman of the Council, to act as their delegate; he attended the Congress, together with a number of the members; and he was elected an Honorary President of the Mining Section. The cordial reception of the Belgian engineers was warmly appreciated by the members of this Institution who attended the International Congress.

A number of the members of the Association des Ingénieurs sortis de l'École de Liége visited England in September, 1904. They attended the Annual General Meeting held at Birmingham, and took part in the proceedings and visits to works, etc. Visits were also made by them to the North of England and South Wales, the arrangements for their entertainment being made by the North of England Institute of Mining and Mechanical Engineers and the South Wales Institute of Engineers respectively.

The International Jury of Awards of the Louisiana Purchase Exposition, 1904, has awarded a Gold Medal to the Institution for the exhibit of the *Transactions* in Group 119, and a Silver Medal to the Secretary, Mr. M. Walton Brown.

The thanks of the members are due to the North of England Institute of Mining and Mechanical Engineers, who have allowed, as hitherto, the Institution to have the use of their offices and stock-rooms during the past year, free of charge.

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Dr. THE TREASURERS IN ACCOUNT WITH FOR THE YEAR

	£ s. d.	£ s. d.
July 31, 1904.		
To Investment with River Tyne Commission	1,000 0 0	
„ Balance at Bank, Current Account	228 10 8	
„ „ „ Deposit Account	413 17 11	
„ „ in Cashier's hands	52 1 7	
		1,694 10 2
July 31, 1905.		
To Subscriptions for the Year ending July 31st, 1902—		
Non-federated—		
Mining Institute of Scotland		0 10 0
To Subscriptions for the Year ending July 31st, 1904—		
Federated—		
Midland Counties Institution of Engineers	6 13 0	
Midland Institute of Mining, Civil and Mechanical Engineers	6 13 0	
Mining Institute of Scotland	0 19 0	
North of England Institute of Mining and Mechanical Engineers	57 19 0	
North Staffordshire Institute of Mining and Mechanical Engineers	5 14 0	
South Staffordshire and Warwickshire Institute of Mining Engineers	14 5 0	
		92 3 0
To Subscriptions for the Year ending July 31st, 1905—		
Federated—		
Manchester Geological and Mining Society	143 9 0	
Midland Counties Institution of Engineers	323 19 0	
Midland Institute of Mining, Civil and Mechanical Engineers	292 16 3	
Mining Institute of Scotland	454 2 0	
North of England Institute of Mining and Mechanical Engineers	1,176 2 0	
North Staffordshire Institute of Mining and Mechanical Engineers	158 13 0	
South Staffordshire and Warwickshire Institute of Mining Engineers	60 16 0	
		2,609 17 3
Non-federated—		
Manchester Geological and Mining Society	25 0 0	
Mining Institute of Scotland	9 0 0	
		34 0 0
Carried forward		£4,431 0 5

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THE INSTITUTION OF MINING ENGINEERS. Cr.
ENDING JULY 31, 1905.

July 31, 1905.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
By Printing—				
Transactions, vol. xxiii., plates ...	9 17 6			
		9 17 6		
„ „ xxiv., plates ...	1 10 0			
		1 10 0		
„ „ xxv., printing ...	109 17 6			
„ „ „ plates ...	19 0 6			
		128 18 0		
„ „ xxvi., printing ...	172 8 3			
„ „ „ plates ...	16 11 3			
		188 19 6		
„ „ xxvii., printing ...	435 9 9			
„ „ „ plates ...	194 19 9			
		630 9 6		
„ „ xxviii., printing ...	548 9 5			
„ „ „ plates ...	154 7 10			
		702 17 3		
„ „ xxix., printing ...	134 2 8			
„ „ „ plates ...	25 5 0			
		159 7 8		
			1,821 19 5	
Excerpts, vol. xxiii.		4 17 6		
„ „ xxv.		6 18 10		
„ „ xxvi.		8 3 6		
„ „ xxvii.		24 5 1		
„ „ xxviii.		53 3 8		
„ „ xxix.		14 5 7		
			111 14 2	
Proofs of Papers for General Meetings		.....	12 12 6	
Circulars		.....	30 6 8	
				1,976 12 9
„ Addressing *Transactions*, etc.		... ...	64 13 7	
„ Stamps—Circulars		12 13 6½		
„ „ Correspondence		28 5 3½		
„ „ *Transactions*		411 14 5		
			452 13 3	
„ Stationery, etc.		.. ...	32 5 2	
„ Insurance of *Transactions*		... ...	3 0 0	
„ Binding—Library		7 6 2		
„ „ Sundries		0 3 6		
„ „ *Transactions*		21 14 3		
			29 3 11	
Carried forward			£581 15 11	£1,976 12 9

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Dr. THE TREASURERS IN ACCOUNT WITH

	£ s. d.	£ s. d.	£ s. d.
Brought forward			4,431 0 5
To Local Publications and Authors' Copies—	1903-1904.	1904-1905.	
The Institution of Mining Engineers	16 8 9	7 11 2	
Manchester Geological and Mining Society ...	0 0 0	7 9 0	
Midland Counties Institution of Engineers ...	0 0 0	0 0 0	
Midland Institute of Mining, Civil and Mechanical Engineers	0 0 0	5 16 9	
Mining Institute of Scotland	0 0 0	7 15 3	
North of England Institute of Mining and Mechanical Engineers	0 0 0	32 1 6	
South Staffordshire and Warwickshire Institute of Mining Engineers	0 14 6	0 10 6	
	17 3 3	61 4 2	78 7 5
To Sales of Transactions, etc.—	1903-1904.	1904-1905.	
The Institution of Mining Engineers	0 0 0	151 7 7	
Midland Counties Institution of Engineers ...	1 0 0	21 13 0	
Midland Institute of Mining, Civil and Mechanical Engineers	5 0 0	5 13 0	
Mining Institute of Scotland	0 0 0	3 13 0	
North of England Institute of Mining and Mechanical Engineers	1 0 0	21 17 0	
North Staffordshire Institute of Mining and Mechanical Engineers	1 0 0	4 13 0	
South Staffordshire and Warwickshire Institute of Mining Engineers	11 0 0	7 2 3	
	19 0 0	215 18 10	234 18 10
To Advertizements		451 16 4	
To Address Labels		1 10 0	
To Interest on Deposit Account		13 3 11	
To Income from Investments		38 0 0	504 10 3
			£5,248 16 11

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THE INSTITUTION OF MINING ENGINEERS.—*Continued.* Cr.

	£ s. d.	£ s. d.	£ s. d.
Brought forward		581 15 11	1,976 12 9
By Reporting General Meetings		34 1 0	
„ Expenses of General Meetings		56 14 8	
„ Incidental Expenses		29 10 11	
„ Salaries, Wages, Auditing, etc.		789 17 6	
„ Indexing *Transactions*		46 4 6	
„ Travelling Expenses		7 18 5	
			1,546 2 11
„ Translation of Papers		3 19 3	
„ Abstracts of Foreign Papers, vol. xxvi. ...	40 0 10		
„ „ „ „ xxvii.	94 5 8		
		134 6 6	
„ Barometer Readings, etc.		5 5 0	
„ Calendars		17 13 6	
„ Prizes for Papers in vols. xxiv. and xxv.		24 0 0	
			185 4 3
			3,707 19 11
„ Adjustment of Excerpts :—			
Mining Institute of Scotland		1 17 0	
			1 17 0
„ Investment with River Tyne Commission		1,000 0 0	
„ Balance at Bank, Current Account		426 17 5	
„ „ „ Deposit Account, including Interest		111 13 9	
„ „ in Cashier's hands		0 8 10	
			1,539 0 0

We have examined the above account of receipts and payments, with the books and vouchers relating thereto, and certify that in our opinion it is correct.

JOHN G. BENSON & SONS,
Chartered Accountants.

Newcastle-upon-Tyne,
August 12th, 1905.

£5,248 16 11

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THE INSTITUTION OF
BALANCE SHEET.—

Liabilities.

July 31, 1905.	£ s. d.	£ s. d.
Sundry Creditors—		
Advertizements paid in Advance	31 2 6	
Printing, etc.	990 0 0	
Postage of Transactions	210 0 0	
Abstracts of Foreign Papers in Volumes xxviii. and xxix.	140 0 0	
Barometer Readings	8 0 0	
Prizes for Papers in Volumes xxvi., xxvii., xxviii. and xxix.	80 0 0	
Indexing Volumes xxvii., xxviii. and xxix.	60 0 0	
		1,519 2 6
Balance of Assets over Liabilities, exclusive of the Value of the Stock of *Transactions*, etc.		411 11 8

We have examined the above Balance Sheet, with the books and vouchers relating thereto, and certify that in our opinion it exhibits a correct view of the affairs of the Institution.

JOHN G. BENSON & SONS,
Chartered Accountants.

Newcastle-upon-Tyne,
March 8th, 1906.

£1,930 14 2

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MINING ENGINEERS.
JULY 31, 1905.

Assets.

July 31, 1905.	£ s. d.	£ s. d.
Balance at Bank, Current Account	426 17 5	
„ „ Deposit Account, including Interest	111 13 9	
„ in Cashier's hands	0 8 10	
Investment with River Tyne Commission	1,000 0 0	
„ „ „ Interest to date	11 2 9	
		1,550 2 9
Subscriptions for the Year ending July 31, 1904, Unpaid—		
Federated—		
South Staffordshire and Warwickshire Institute of Mining Engineers	2 17 0	
		2 17 0
Subscriptions for the Year ending July 31, 1905, Unpaid—		
Federated—		
Manchester Geological and Mining Society	23 15 0	
Midland Counties Institution of Engineers	14 5 0	
Midland Institute of Mining, Civil and Mechanical Engineers	13 1 9	
Mining Institute of Scotland	1 18 0	
North of England Institute of Mining and Mechanical Engineers	87 8 0	
North Staffordshire Institute of Mining and Mechanical Engineers	9 10 0	
South Staffordshire and Warwickshire Institute of Mining Engineers	37 1 0	
		186 18 9
Non-federated—		
Manchester Geological and Mining Society	3 0 0	
		3 0 0
Local Publications and Authors' Copies, Unpaid—		
Institution of Mining Engineers	17 16 6	
Mining Institute of Scotland	2 3 0	
North Staffordshire Institute of Mining and Mechanical Engineers	1 1 6	
South Staffordshire and Warwickshire Institute of Mining Engineers	4 6 3	
		25 7 3
Transactions Sold, Unpaid—		
Midland Counties Institution of Engineers	8 0 0	
North of England Institute of Mining and Mechanical Engineers	1 0 0	
South Staffordshire and Warwickshire Institute of Mining Engineers	3 0 0	
		12 0 0
Advertizements, Unpaid		150 8 5
		£1,930 14 2

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The Local Institutes in Account with The Institution of Mining Engineers, for the Year Ending July 31st, 1905.

Dr.

	No. of Members: Federated	No. of Members: Non-federated	Balance due at the beginning of the year	Amounts falling due during the Year: Calls made during the year	Excerpts	Transactions, etc.	Totals
			£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Manchester Geological and Mining Society	176	56	0 0 0	195 4 0	7 9 0	0 0 0	202 13 0
Midland Counties Institution of Engineers	356	...	7 13 0	338 4 0	0 0 0	29 13 0	375 10 0
Midland Institute of Mining, Civil and Mechanical Engineers	322	...	11 13 0	305 18 0	5 16 9	5 13 0	329 0 9
Mining Institute of Scotland	480	18	0 19 0	465 0 0	9 18 3	4 3 0	480 0 3
North of England Institute of Mining and Mechanical Engineers	1,330	...	58 19 0	1,263 10 0	32 1 6	22 17 0	1,377 7 6
North Staffordshire Institute of Mining and Mechanical Engineers	177	...	6 14 0	168 3 0	1 1 6	4 13 0	180 11 6
South Staffordshire and Warwickshire Institute of Mining Engineers	103	...	28 16 6	97 17 0	4 16 9	10 2 3	141 12 6
Totals	2,944	74	114 14 6	2,833 16 0	61 3 9	77 1 3	3,086 15 6

Cr.

	Amounts Paid during the Year: Balance from previous year	Calls	Excerpts	Transactions, etc.	Totals	Balance due at July 31st, 1905
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Manchester Geological and Mining Society	0 0 0	168 9 0	7 9 0	0 0 0	175 18 0	26 15 0
Midland Counties Institution of Engineers	7 13 0	323 19 0	0 0 0	21 13 0	353 5 0	22 5 0
Midland Institute of Mining, Civil and Mechanical Engineers	11 13 0	292 16 3	5 16 9	5 13 0	315 19 0	13 1 9
Mining Institute of Scotland	0 19 0	463 2 0	7 15 3	4 3 0	475 19 3	4 1 0
North of England Institute of Mining and Mechanical Engineers	58 19 0	1,176 2 0	32 1 6	21 17 0	1,288 19 6	88 8 0
North Staffordshire Institute of Mining and Mechanical Engineers	6 14 0	158 13 0	0 0 0	4 13 0	170 0 0	10 11 6
South Staffordshire and Warwickshire Institute of Mining Engineers	25 19 6	60 16 0	0 10 6	7 2 3	94 8 3	17 1 3
Totals	111 17 6	2,643 17 3	53 13 0	65 1 3	2,871 9 0	212 6 6

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BOOKS, ETC., ADDED TO THE LIBRARY.

African Review, London. Vol. xl., Nos. 611-619; and vol. xli., Nos. 620-632.
Annales des Mines de Belgique, Bruxelles. Vol. ix., Nos. 3 and 4; and vol. x., Nos. 1-3.
Australasian Institute of Mining Engineers, Melbourne. Transactions, vol. x.
British Association for the Advancement of Science, London. Report of the Seventy-third Meeting, held at Southport in September, 1903; and Report of the Seventy-fourth Meeting, held at Cambridge in August, 1904.
British Society of Mining Students, Manchester. Journal, vol. xxvi., Nos. 1-6 and Index; and vol. xxvii., Nos. 1-4.
Chemical and Metallurgical Society of South Africa, Johannesburg. Journal, vol. iv., No. 12; and vol. v., Nos. 1-12.
Cory Brothers & Company, Limited, Cardiff. British Coal and Freight Circular and General Export List, July 31st, 1904, to April 30th, 1905.
Cuerpo de Ingenieros de Minas del Perú, Lima. Boletín, Nos. 8 and 10-23.
Engineering and Mining Journal, New York City. Vol. lxxviii., Nos. 4-26; vol. lxxix., Nos. 1-26; and vol. lxxx. Nos. 1-4.
Engineering Times, London. Vol. xii., Nos. 78-98; vol. xiii., Nos. 99-124; and vol. xiv., Nos. 125-130.
Franklin Institute of the State of Pennsylvania, Philadelphia. Journal, vol. clviii., Nos. 2-6; vol. clix., Nos. 1-6; and vol. clx., No. 1.
Geological Institution of the University of Upsala, Upsala. Bulletin, vol. vi., Nos. 11 and 12.
Institution of Mining and Metallurgy, London. Transactions, vols. xii. and xiii.
Manchester Geological and Mining Society, Manchester. Transactions, vol. xxviii., Nos. 16-20.
Massachusetts Institute of Technology, Society of Arts, Boston. Technology Quarterly, vol. xvii., Nos. 2-4; and vol. xviii., No. 1.
Mining Society of Nova Scotia, Halifax. Transactions, vol. viii.
New South Wales, Department of Mines, Sydney. Annual Report, 1904.
New Zealand, Department of Mines, Wellington. Annual Report, 1904.
Queensland, Department of Mines, Brisbane. Annual Report, 1904.
—, — — —, —. Year-book, 1905.
Queensland Government Mining Journal, Brisbane. Vol. v., Nos. 49-55; and vol. vi., Nos. 56-60.
South Wales Institute of Engineers, Cardiff. Transactions, vol. xxiv., Nos. 1-4.
United States, Geological Survey, Washington. Bulletin, Nos. 228-241.
—, —, —. Mineral Resources of the United States, 1903.
—, —, —. Professional Papers, Nos. 22-28.
—, —, —. Water-supply and Irrigation Papers, Nos. 95-118.
Western Australia, Department of Mines, Perth. Annual Report, 1903.

EXCHANGES.

Annales des Mines de Belgique.
Australasian Institute of Mining Engineers.
British Association for the Advancement of Science.
British Society of Mining Students.

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*Canadian Mining Institute.
Chemical and Metallurgical Society of South Africa.
Cuerpo de Ingenieros de Minas del Perú.
Franklin Institute of the State of Pennsylvania.
Geological Institution of the University of Upsala.
*Institution of Mechanical Engineers.
Institution of Mining and Metallurgy.
*Lake Superior Mining Institute.
Massachusetts Institute of Technology.
Mining Society of Nova Scotia.
*Natal, Geological Survey of the Colony of.
New South Wales, Department of Mines and Agriculture, Geological Survey.
*North-east Coast Institution of Engineers and Shipbuilders.
*Revue Universelle des Mines, de la Métallurgie, etc.
South Wales Institute of Engineers.
*Transvaal, Department of the Mining Commissioner.
United States Geological Survey.

* No publications received during the current year.

July 31st, 1905.

The PRESIDENT (Sir Lees Knowles, Bart.) then took the chair.

Mr. JOSEPH DICKINSON read the following paper on "The Leading Features of the Lancashire Coal-field":—

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THE LEADING FEATURES OF THE LANCASHIRE COAL-FIELD.

By JOSEPH DICKINSON, F.G.S.

I.—Introduction.

The Lancashire coal-field has been described by numerous authors. Many of the monographs appear in the *Transactions* of the Manchester Geological (and now Mining) Society. The first two of these in 1839, followed by a third in 1840, were written by that able pioneer and practical geologist, Mr. Edward William Binney, who added many others afterwards. Following on in 1862, came the present writer's first paper, with a detached sheet of sections of the strata, some of which were by eminent mining engineers whose names are duly acknowledged in the text.* It would be a long list to specify all the writers. Suffice it to say that in 1904, came one by Mr. Herbert Bolton on the palæontology, and one on the Bradford (Manchester) part of the coal-field by Mr. John Gerrard.

In 1865, at the request of the Lancashire and Cheshire Coal Association, the present writer gave to the North of England Institute of Mining Engineers, on their visit to Manchester, a short paper on "Some of the Leading Features of the Lancashire Coal-field," which is printed in their Transactions.† Being now asked by the Council of the Manchester Geological and Mining Society to give a paper on the same subject to The Institution of Mining Engineers on the occasion of their 1905 visit to Manchester, and since it is superfluous to repeat details, what he now proposes is to outline very briefly the 1865 paper, and with additions to endeavour to bring it up to date.

II.—Outline.

The maximum thickness of the Carboniferous formation in Lancashire is about 4,850 yards. This consists of:—The Coal-

* *Transactions of the Manchester Geological Society*, 1862, vol. iv., page 155.

† *Trans. N. E. Inst.*, 1865, vol. xv., page 13.

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measures, about 2,150 yards; the Millstone Grit, with accompanying strata, 2,000 yards; and the Mountain Limestone, 700 yards.

The coal-field in point of thickness, number of seams and variety of coal, is comparable with the thickest coal-fields of the kingdom.

The Millstone Grit, notably between Burnley and Chatburn, differs very much from the thin representative strata of farewell rocks, shales and conglomerate, as seen on the northern outcrop in South Wales, or as compared with the much thinner representative between Durham and Cumberland.

The Mountain Limestone, next below, is more divided into masses with intermediate strata and the usual minor divisional bedding, than the more solid mass in Wales, the division into masses being completed further north.

The outcrops of the coal-field are traceable round the outskirts, the crop of the lower coal-seams being mainly on high ground. These outcrops are not always in parallel lines, but often disconnected and altered by change of dip and faults. The chord-line, across where the coal-field is overlain by unconformable New Red Sandstone, Permian Marls and Permian Sandstone, is usually of low elevation.

Consequent upon the great thickness of the coal-field, it has been found convenient by mining engineers to divide it into three series—the Upper, Middle and Lower. The Upper Series counts from the top down to and including the Worsley and Pendleton Top Four-foot seam. The Middle Series, from the Worsley Four-foot down to and including the Arley seam. The Lower Series from the Arley down to the lowest seam: this Lower Series, from the fact that many of the outcrops are on the hills, is sometimes called the Mountain Mine Series. The coal in the Upper Series is usually swifter burning than that in the other series—the Worsley Four-foot having long been prized as suitable for bakers' ovens and shortage of boiler-power. Other seams are often known by names corresponding to the special purposes which they suit. Some geologists have demurred to the division of the coal-field into series; but, for ordinary practical purposes, the division is found too convenient to be given up.

In dealing with numerous sections of strata it should be understood that in some the thickness is measured at a right

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angle to the bedding, whilst in others (as in vertical shafts through dipping strata) it is usually measured vertically, which shows more thickness. Consequently, in comparing sections, allowance is required for the difference. And further, actual discrepancies have sometimes to be rectified in sections of shafts and bore-holes which pass through faults, the throw of which causes some strata to be missed and lessens the distance to lower seams; whilst on rare occasions, in contorted strata, a vertical shaft might pass three times through the same seam.

III.—Variations in the Coal-field.

Tracing the coal-field from point to point, some strata are found continuing over long distances with few changes, and others changing variously. These variations arise from:—(*a*) Faults; (*b*) changes of dip; (*c*) intervening strata; and (*d*) variation of coal-seams.

The following are instances of change:—

(*a*) *Faults.*—Faults cause the greatest displacements. They are numerous, and the coal has to be worked in the belts between them.

The largest fault comes through Bolton and by the Irwell valley to Pendleton. At Darcy Lever Hall, the Worsley Top Four-foot coal, at the bottom of the Upper Series, crops out against the downthrow side of the fault, and at the opposite side are the strata near the bottom of the Middle Series, showing a throw of about 1,000 yards, and for 3 miles southwards the Four-foot coal and strata above it are absent. At Pendleton, where the crop of the Four-foot comes against the upthrow side of the fault, New Red Sandstone and Permian are in at the downthrow side; (from underneath which, about 2 miles northwards, the Four-foot emerges) the difference of distance at the reverse positions being occasioned by difference of dip. This great fault has been cut through, and, as seen by the writer, was found to be of great width, verifying the old observation "the wider the fault-vein the greater the throw."

(*b*) *Changes of Dip.*—Changes of dip come next in varying the courses. The dip east of Blackburn through Great Harwood is almost vertical, with the summit occasionally turned over in the reverse direction, and different elsewhere. Dips in the

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interior vary from 1 in 2 to nearly horizontal. Common dips are 1 in 3 and 1 in 5.

The overlying unconformable formations usually dip in similar direction with the coal-bearing strata, but generally at a different rate.

(*c*) *Intervening Strata.*—New beds intervening sometimes occasion change, which, unless followed step by step, is difficult to trace. Sandstone-rocks are perhaps the most intrusive. With them, as is sometimes said, "the coarser the structure, the shorter the range."

(*d*) *Variations of Coal-seams.*—Variations of coal-seams are often very important. Dirt-bands come in between the beds of some coal-seams, and occasionally thicken into varied strata, and then further away the coal-beds either re-unite or become dispersed.

IV.—The Coal-measures.

Upper Series.—The Worsley and Pendleton Top Four-foot seam, at the base of this series, is an instance of long continuance with little change. It has been extensively worked south of the Irwell-valley fault from Bedford-Leigh, through Astley, Worsley, Patricroft and Pendlebury to Pendleton, in the course of which it is crossed by large faults. It has also been worked north of the Irwell-valley fault, from Darcy Lever Hall, ¼ mile north-west of the confluence of the Croal with the Irwell to 2½ miles eastwards.

Instances of change in this Upper Series are given in part V. of this paper, on the Manchester portion of the coal-field, in which the correlation of this Four-foot seam has long been debatable.

Middle Series.—In the Middle Series are many changes, of which the following are some, in descending order:—

The Ince and Gidlow group of coal-seams at Wigan become the Binn, Shuttle, Crumbouke, Brassy and Rams eastwards. In this course, the seam now generally called the Rams, has been and is still occasionally known as the Seven-foot and the Six-foot. At Clifton, the Shuttle and Crumbouke lie 15 yards apart: at Great Lever, Little Lever and Radcliffe, they are united and form the Upper Three-yard. The Brassy seam,

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between the Crumbouke and the Rams, entirely disappears between Clifton and Pendlebury colliery, being replaced by sandstone-rock; and, in the same range, the top coal of the Rams disappears.

The Pemberton Five-foot, Two-foot and Four-foot, respectively 12 and 15 yards apart at Wigan, maintain about the same lie as far as Haydock where they are named the Florida, but at St. Helens they become apparently the Higher and Lower Main delf, only 4 yards apart. East of Wigan, at Abram, Westleigh, Tyldesley and Shakerley, the Two-foot and Four-foot are united as the Great Seven-foot; farther east, separation sets in, so that at Worsley, Kersley, Clifton and Pendlebury they are the White and Black seams, 30 yards apart. Near Bolton, the beds are united as the Lower Three-yard or Ten-foot, which continues until the lower part separates into a distinct seam called the Gingham: the Ten-foot above holding on. Farther east, at Radcliffe Bridge, the beds become so separated as to have as yet been but little worked.

The wellknown Wigan Cannel coal (now represented mainly by exhausted workings) and the King coal-seam below, undergo many changes. Elsewhere, the Cannel disappears, and is often replaced by ordinary coal, with the King coal diverging, as at Westhoughton, to 17 yards or so, and becoming known as the Sapling. Farther away, at Stonecleugh, Clifton, Ainsworth, Radcliffe and Elton, with sometimes a trace of cannel on the top, the seam has been extensively worked. At Elton, it becomes known as the Hynes mine, with the Sapling coming close up near Bury. Then, beyond a large vacant area, at Middleton, the seams are usually considered to correlate with the Bent mines united, and at Oldham as the Upper and Lower Bent seams, and at Ashton-under-Lyne as the Two-foot and Peacock, about 20 yards apart.

The Wigan Plodder, Yard, Half-yard, Three-quarter, and the Arley group are the lowest seams of the Middle Series. The Yard and the Arley have been extensively worked, the others partially. Most of these seams thin eastwards, some disappear, and, north of the Irwell-valley fault, they are almost entirely unrecognized. At Elton and Bury, a coarse thick seam called the Dogshaw appears (after a few traces), and has been worked. The Dogshaw from its position has been assumed to be

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the Arley; but, from other associations, it seems more likely to be the Plodder revived. Beyond Bury, the entire Middle Series disappears for some distance. A seam reappears in similar position at Rochdale, Heywood, and other detached places, and is called the Royley. The corresponding seam is also called the Royley, where the main coal-field crops out east of Oldham and Ashton-under-Lyne.

In the Burnley part of the coal-field, where the Middle Series reappears, the lowest seam in the series was formerly called a Four-foot, but latterly for distinction has been called the Arley.

A shell-bed, with remarkably large fossil shells, long called *Anthracosia* (but now seemingly referred to as *Anthracomya* or *Carbonicola robusta*), lies a few yards above the Arley mine at Wigan and in the vicinity.

Lower Series.—In the Lower Series, variations occur similar to those described in the Upper and Middle Series. Several of them are mentioned in the writer's former papers, and need not be repeated here. Suffice it to mention the change in position between the Upper Foot and the Gannister coal-seams. For a long range north-east of Oldham, these two seams lie about 15 yards apart. In the Upper Foot coal are spherical concretions, called "bullions," and in the roof over the coal are lenticular cakes containing numerous fossil shells (*Goniatites*, etc.) and some vegetable matter. When struck, these cakes emit an odour like garlic. The water from the coal, etc., yields much ochre, and, like nitric acid, it temporarily discolours a person's skin. Near Portsmouth (Cliviger), and Tooter Hill (Bacup), and notably Wholaw old colliery (3 miles south of Burnley), where the writer has seen the transition, the Upper Foot dips steeply down and unites with the Gannister coal. The two seams continue united as the Gannister Four-foot through the Burnley part of the coal-field to Colne, with the same characteristics continuing as those appertaining to the Foot coal before the union. The same kind of fossils also appear with the seam at Ingleton in Yorkshire, and are of great diagnostic value. At Wholaw, where the seams unite, the floor contains masses of iron-pyrites.

It is only the Lower Series which connects the Burnley part with the main coal-field. It is an improving series northwards, appearing ultimately, in greatly expanded form, as the great Durham and Northumberland coal-field.

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V.—Manchester Portion of the Coal-field.

The Manchester portion of the Lancashire coal-field requires special mention. It is surrounded by large faults and unconformable New Red Sandstone and Permian.

As it is thus isolated from the main coal-field, with the strata varied and different nomenclature of seams, diverse opinions have long been held on the correlation. The debates have centred chiefly on the question whether the Bradford (Manchester) Four-foot coal is identical with the Worsley and Pendleton Top Four-foot.

In 1879, Mr. Clegg Livesey, one of the old firm of owners of the Bradford colliery, in giving the section of strata of the Parker pit to the Manchester Geological Society, stated that formerly the firm supposed the Bradford Four-foot to lie about 300 yards above the Pendleton Crumbouke and Rams group of seams, but that after many explorations, one a shaft extending through the Bradford Four-foot at 110 yards to a thick rock and then by bore-hole to a total depth of 700 yards, they failed to find the Crumbouke and Rams series, the best seam met with being at 550 yards and that only about 3 feet in thickness, which they had named the Parker after the lord of the manor, and were working.*

Since the decease of Mr. Livesey, the present owners of Bradford colliery have extended the explorations to nearly 350 yards below the Parker mine, where they have found coal to which they are sinking, and expect to reach it by a shaft at a depth of about 900 yards below the surface. A cross-measure drift, dipping steeply across the strata, which dip at the rate of about 1 in 3, has already reached the coal, and the shaft has passed through the Parker.

The continuous section thus proved at Manchester consists of:—

	Yards.	Yards.
Ardwick Limestone, in twelve beds (24 feet 10 inches) with strata		157
Coal-measures cropping out to top of Bradford shafts		330
Bradford shafts to Bradford Four-foot	110	
Do. do. below Bradford Four-foot to Parker ...	440	
Do. drift, below Parker seam to coal	350	
		900
Total thickness proved		1387

* "Section of Strata at Bradford Colliery," by Mr. Clegg Livesey, *Transactions of the Manchester Geological Society*, 1879, vol. xv., page 161.

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The principal beds of the Ardwick Limestone have been worked extensively. The mines are now closed, and the deep shaft is used as a pumping-station; it seems desirable, therefore, to repeat the section furnished several years ago by Mr. William Mellor, who managed the mines for many years.

SECTION OF THE ARDWICK LIMESTONE STRATA, MANCHESTER.

Commencing (under 4 feet 6 inches of marl) below the Permian Sandstone.

Description of Strata.	Thickness. Ft.	In.	Depth. Ft.	In.
First Limestone ...	1	2	1	2
Dark clay-floor, 8 inches; red clay, 10 feet ..	10	8	11	10
Second Limestone, with open joints	1	4	13	2
Grey clay-floor, 6 inches; clay, 11 feet	11	6	24	8
Third Limestone ...	1	4	26	0
Hard red clay	13	6	39	6
Fourth Limestone ...	0	10	40	4
Very hard red clay ...	36	0	76	4
Fifth Limestone ...	1	0	77	4
Grey and red clays ...	24	0	101	4
Sixth Limestone ..	2	0	103	4
Clay, 23 feet; gritstone, 1 foot; gritty shale, 21 feet; clays, 54 feet	99	0	202	4
Seventh Limestone ...	4	0	206	4
Red and green shale-beds	15	0	221	4
Eighth Limestone .	3	0	224	4
Red and green clays ...	4	0	228	4
Ninth Limestone (occasional)	1	0	229	4
Clays and shales, with calcareous courses ...	15	0	244	4
Tenth Limestone ...	1	6	245	10
Shales and grits, 45 feet; coal and black-band ironstone, 1 foot 6 inches; and sandy shale, 6 feet	52	6	298	4
Eleventh Limestone, main seam in six beds, limestone, 5 feet 4 inches; shale, 3 feet 8 inches	9	0	307	4
Red, etc., shale, 60 feet; COAL, 6 inches; floor, 6 feet	66	6	373	10
Large calcareous nodules	0	10	374	8
Shale and Holt Town sandstone, 81 feet; red shale, 15 feet ...	96	0	470	8
Twelfth Limestone and red ironstone ...	2	0	472	8

Some of the limestone is of brecciated structure. The lime produced has the property of a slowly-setting cement, which for many years was highly valued as the best for bricking in colliery-shafts.

The colliery-workings in the Manchester portion have extended from near the river Irk (partly under the slope of St. George's fault, Rochdale road), to beyond Belle Vue, Hyde road, a distance of 3 miles on the level course. Several seams of coal have been worked, most of them thin:—The Openshaw seam, to a small extent, chiefly for fire-clay; the Charlotte, Three-quarter, Four-foot, Yard and Parker; also a little of the New, the Doctor, and Two-foot, which lie between the Yard and the Parker. A thin coal and fire-clay have also been mined to a small extent at Hendon Vale, Smedley, in the valley of the Irk.

Most of the workings were closed before the 1872 Coal-mines Regulation Act first made the deposit of record-plans obligatory.

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This requirement, now continued by the 1887 continuing Act, makes such deposits private for 10 years, except with the owner's consent. But under the 1896 Act, view is allowed for purpose of safety, with consent of the Secretary of State. Consequently, plans of the earlier workings were not so deposited. But the plan of the Bradford Four-foot was so deposited, and 10 years having expired, it is free to be viewed at the Home Office, Whitehall, London. The plan throws much light on this part of the coal-field; and it is an instructive record of how the extensive dip-workings were won underneath the dead water of former workings, and how in parts of deep workings pillars (40 yards wide with 20 yards workings between) were considered best for surface-support.

Strangers viewing this plan of the Four-foot mine may wonder what stopped the extension of the workings northwards to St. George's fault. The reason is said to be one of the cautions against disposing of property in small holdings without reserving the minerals.

As to the correlation of the strata of the Manchester part of the coal-field with the strata at Pendleton, it may be thought an easy task, having about 1,387 yards for the comparison. The writer of this paper has long known the upper part of the section. Now he has been kindly made acquainted with the lower portion. Yet throughout the whole, the division of seams precludes hasty identification. The additional evidence appears to strengthen the view that the Bradford (Manchester) Four-foot coal-seam is identical with the Pendleton and Worsley Top Four-foot.

The difficulty of reconciling this view has all along been the absence, from the Bradford strata, of seams of coal corresponding with those that occur in the Rams group west of Manchester. Actual proof is still wanting. In endeavouring to explain this want, the writer is forced to the conclusion that, at Bradford, important portions of this group have become displaced by the thick sandstone-rock, 300 yards below the Four-foot coal. He describes, in Part IV. of this paper, the proved displacement at Pendlebury of the whole of the Brassy seam from this group by the intervention of sandstone-rock. Apparently, therefore, the displacement is increased at Bradford.

As to the lower seams at Bradford, the Parker, (a white-ash coal) probably accords with the White coal of the Pemberton

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group; and the deeper seams in varied form accord with seams in lower groups.

As to the correlation with seams east of Manchester, the Pendleton Shuttle and Crumbouke and the Three-yard of Radcliffe (of the Rams group) apparently accord with the Stanley seam at Moston and the Roger at Ashton-under-Lyne.

Mention has recently been made of the discovery in the new shaft at Bradford, of a bed of limestone 1 foot thick containing the small *Spirorbis*, between the Bradford Three-quarter and Four-foot seams, usually of diagnostic value; but since no corresponding stratum has yet been noticed either at Pendleton or Patricroft, west of Manchester, this find does not help the correlation.

VI.—The Overlying New Red Sandstone and Permian.

At the time when the 1865 paper was written, the New Red Sandstone and Permians overlying the Lancashire coal-field were often grouped by mining engineers as the "red rock." Since then, the distinctions have become generally recognized, although some changes have occurred from time to time, even in high quarters, on the acquisition of matured information.

The Ardwick Limestone, overlying the Manchester portion of the coal-field, was once classed sometimes with part of the Magnesian Limestone; but the two thin coal-seams and fossils cause it at present to be classed with the Coal-measures.

The Manchester "red rock" of old is now generally divided into:—

New Red Sandstone, with pebbles in the lower portion: say, about 400 yards.

Permian Marls, the lower portion with numerous thin fossiliferous limestones in beds and lenticular cakes; and, at the bottom, a bed of conglomerate about 3 feet thick, total, 60 to 86 yards: say, 70 yards.

Permian Sandstone, soft, part being good moulding-sand. Bored through at Droylesden, 250 yards, and at Heaton Park 278 yards: say, 270 yards.

The New Red Sandstone and the Permians, although thrown by the same large faults, are unconformable with the coal-strata. The rates of dip are different, and so are the positions of the coal-bearing strata where the covering comes on. At Ardwick

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(Manchester), the Permian Sandstone comes on almost close above the highest proved bed of Ardwick Limestone; and (including the 157 yards of Ardwick Limestone) about 600 yards above the Bradford (Manchester) Four-foot coal. At Patricroft abandoned colliery, the Permian Marls come on at about 350 yards above the Worsley and Pendleton Top Four-foot. Thus, assuming the Bradford Four-foot to correlate with this seam, this implies a decrease westward of 250 yards in 6 miles, and the ratio continues. At Nock pits, Astley, near Tyldesley, 5 miles farther west, it is only about 113 yards above the same Four-foot: a decrease of 237 yards in 5 miles. At Milner's abandoned colliery, a mile still farther west, it is about 90 yards, a decrease of 23 yards. The average decrease (510 yards in 12 miles) is about 42 yards per mile. Farther west yet, at Plank Lane colliery (Westleigh), and at Maypole (Abram), the Four-foot seam ceases to crop out, being covered by the New Red Sandstone and Permian.

Water is pumped in large quantities from the New Red Sandstone, Permian and Coal-measure sandstones; and deeper wells sometimes drain the shallower. When Mr. Thomas Livesey's trial-shaft entered the thick Coal-measure sandstone, it drained the Newton Heath brewery-well, which continued whilst the shaft was unwatered. Contrarywise, when the Droylesden bore-hole was in the Permian Sandstone, 110 feet below sea-level, all the water to that depth went away and sand was washed with it; and when boring ceased at a depth of 1,300 feet, the bottom part was puddled, to assist in preventing water from passing down into future workings.

Pumping-stations in watery New Red Sandstone and Permian, overlying colliery-workings, require watching lest the well might be deepened and thus flood the colliery. This applies especially where workings unknown to the well-owner are under the slope of a fault. For many years past, a continuous barrier of coal has been left against the overhanging Irwell-valley fault.

VII.—Conclusion.

The general outline of the coal-field is semi-circular, with unconformable New Red Sandstone and Permian at the chord, under which it dips, to re-emerge on the opposite side of the basin in North Staffordshire, North Wales, and the Wirral peninsula.

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It is dislocated by large faults, altered by dips, change of strata, including coal-seams. Each fault, as usual, slopes towards the downthrow side at an obtuse angle from the bedding of the strata, no matter how the strata dip.

The largest fault has corresponding strata, 1,000 yards higher at one side than at the other side; but the surface of the ground is levelled off to the same altitude at both sides, similarly to other faults. Over this levelled-off surface, there is ordinarily, up to a certain elevation, a covering of drift composed of clay, sand and pebbles, dragged or conveyed from distant outcrops, the whole lying unconformably upon the strata beneath. These disappearances of strata from the upthrow side of faults, and the disappearances of very much larger masses of ground shown by vacancies, are accounted for geologically by imaginary denudation and ice-flows.

Vast areas of the best coal-seams at moderate depths have been worked: some entirely, leaving the vacant goaf compressed between the roof and floor of the mine; and some with pillars of coal, varying from one-fourth to two-thirds of the whole, left purposely for surface-support.

Workings have already attained a depth exceeding 1,160 yards below the surface.

Places for new winnings within the area of the coal-field proper are few and difficult to find; thus, forcing an increasing number of sinkings to pierce the overlying watery formations on the dip.

Possibly the first surprise of the intelligent mining engineer-visitor from comparatively faultless coal-fields may be to find that, among such large dislocations, coal is produced from between the belts as cheaply as in many other districts.

Mr. JAMES ASHWORTH proposed a vote of thanks to Mr. Dickinson for his interesting paper.

The PRESIDENT (Sir Lees Knowles) seconded the vote of thanks, which was cordially adopted.

Mr. R. L. GAMLEN read the following paper on "Electric Power-distribution:—

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ELECTRICAL POWER-DISTRIBUTION.

By ROBERT LORAINE GAMLEN.

Although electricity in a vague way has been known for many hundreds of years, it is only lately that it has been made use of commercially. Its history is remarkable, more particularly as its application has progressed almost geometrically, at first slowly, then more quickly, until now the advance is so rapid that it is practically impossible to keep pace with the developments of the science.

The early experiments of Volta, Michael Faraday, and others, though they paved the way for all that is to-day, are too academic for this sketch. Perhaps 1856 marks the time when electricity was used at all for lighting commercially. In that year, the Siemens armature was invented, and from that date onward the light was used for lighthouses—in those days the only field-magnet used was the permanent steel magnet. In 1867, another and most radical advance was made: Siemens and Wheatstone supplanted the permanent magnet by the electro-magnet, and this advance gave the commercial dynamo.

In 1875, some arc-lamps were erected in Liverpool. From that date, various small sets with one engine, one dynamo and one arc-light were put on the market; they were used for lighting large open spaces, and still in 1879, Sir William Preece reported that "the electric light is only economical when one machine is used to produce one light." In 1878, the first arc-lighting stations were opened in London, when the Jablochkoff Company lit the Thames Embankment and the Holborn Viaduct. This was by means of the old Jablochkoff candles, which have long since been forgotten.

In 1878, Edison first brought out a form of incandescent lamp, the filament being of platinum-wire. In 1879, Sir Joseph Wilson Swan exhibited the first carbon-filament lamp at Newcastle-upon-Tyne. The possibilities of electricity, even in those

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days, were so obvious that all the gas-shares throughout the country fell; as usual, in such cases, the slump went to preposterous lengths—electrical concerns also got an exaggerated support. The Anglo-American Brush Company took most advantage of this boom.

From 1880 onwards, the electric light-supply business has been in existence. In 1881, the Metropolitan Brush Company started a bulk-supply in London, and in 1882, the Jablochkoff Company erected another supply-station at Belvedere Road, for supplying both incandescent and arc-lighting in the Strand district.

Among the pioneers were the Colchester, Hastings and Eastbourne concerns, and several small concerns in London. These undertakings were worked in different ways:—(1) High-pressure direct-current machines: the Brush arc-lighter working with lamps placed in series across the terminals, both arc and incandescent. (2) High-pressure single-phase alternating, when the current was generated at the high pressure of 2,000 volts and distributed to transformers, there being converted to a working pressure of 50 to 100 volts. (3) Also in very condensed areas, direct-current systems were in use. Owing to the price of copper, high tension soon became a general practice, the facility of transformation, and the fact that the alternator had no commutator (always a source of trouble in the old direct-current machines), brought the single-phase alternating-current system into universal use, and for some considerable time this system was almost always adopted. This system developed, and in 1885, the London Electric Supply Corporation made a remarkable advance by putting down a station at 10,000 volts, thus early showing the way for the power-companies. Then, however, they had single-phase current only, and although they had the facility of transmission, they had not the means of turning the electrical power back into mechanical work. The single-phase motor was only a toy in those days; but that was not the only obstacle to the expansion of the industry. In 1882, the first Electric Lighting Act was passed, giving the Board of Trade powers to grant provisional orders to local authorities and companies for supply in certain areas. The local authorities possessed powers in perpetuity: the companies on the other hand had only 21 years, at the end of which time the local

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authority could purchase the undertaking at the structural or scrap-iron value; and this, to a great extent, put a stop to electrical enterprise.

In the first year, 69 Orders were applied for, and as the applicants could not get any capital, in 1884 only four Provisional Orders were applied for, and in 1885 only one. It was not until 1888, when the Act was amended, extending the term of tenure to 42 years, that electric lighting by private enterprise became commercially possible.

The problem in the early days was practically that of lighting only, and, so far as that was concerned, the alternating single-phase system met the case admirably; but the plant had to be kept running all the 24 hours, although the hours during which light was used were from ¼ hour to 3 hours in the summer, to 6 or 7 hours in the winter: consequently, the cost of running such undertakings was enormous. The interest-charges per unit sold were high, and the actual production-costs during the long idle hours swamped the concern. The enormous copper-expenditure that would have been necessary in low-tension mains, however, kept the system in force. The doubling of the pressure by the three-wire system altered conditions to a great extent: as then, with the use of a battery, the hours during which the machines had to turn were enormously reduced. The manufacture of the high-voltage lamp completed the change, and then all the new stations were built on the direct system, with generally three-wire distribution, and usually a declared pressure of from 200 to 250 volts. This change took place in about 1896. Although a great improvement had been made by the change, still the costs were high (not so much the actual working costs as the capital charges) owing to the short hours during which useful work was being done. The change to direct-current working gave the undertakings a chance to better their positions by taking on power-consumers during the day; many of the energetic concerns tried to make the best use possible of the chance, and to a large extent they met with great success, but they soon found many drawbacks. Owing to the large capital-expenditure in copper, necessary to transmit high powers, and to the fact that there was always a period of severe load when the lighting and power overlapped: and also, owing to the many

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disadvantages inherent in a concern put down in the middle of a town and laid out to cater first for lighting, the price could not be brought down low enough to compete with the prices at which many industries could generate for themselves. These difficulties were soon recognized, and in 1900 the first of the power-company bills went before Parliament, aiming, by their great size and the variety of the industries which they could serve, at an economical method of dealing with the demand for cheap electricity.

Until quite recently in London, electricity was sold universally at 8d. per unit, but now the new Administrative County of London Company (whose bill, after steering through the extreme difficulties of the Committees of the House, and in the teeth of violent opposition, failed only to become law because of a day or two's time) has limited itself to a maximum price of 1½d., and prices as low as ½d. per unit in some special cases have been reached. As lately as two years ago, no coal-mines in this country took electricity from outside sources; but now power-companies have over 12,000 horsepower connected to their mains for collieries alone. These facts show clearly, then, that a vast change has taken place. It has been an evolution and an expansion, and a remarkably rapid one.

A typical case of a concern which has grown up and tried to cope with the changing conditions is the following:—

A lighting scheme was decided upon in 1896, and, as lighting was the only object at that time, naturally alternate current was used. As the area was an extensive one, this served the purpose well; but, owing to the large capital and working expenses, there was a steady and regular loss. After a few years, the township wished to instal an electric-tramway system, and in consequence a direct-current system was then adopted. Still, owing to peak-load vagaries, a very large margin had to be allowed, and in order to help matters on vigorous steps were taken to obtain other motor-load. This effort met with success, but now the problem of transmitting the large power at present needed comes up, and shortly it will be needful to add a three-phase distribution to the existing plant. This case is representative of nearly all those concerns that have been at work for more than six or seven years, and one that has come out of its troubles so far

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remarkably well; yet it is at best a compromise and a patchwork affair, and far enough from the ideal.

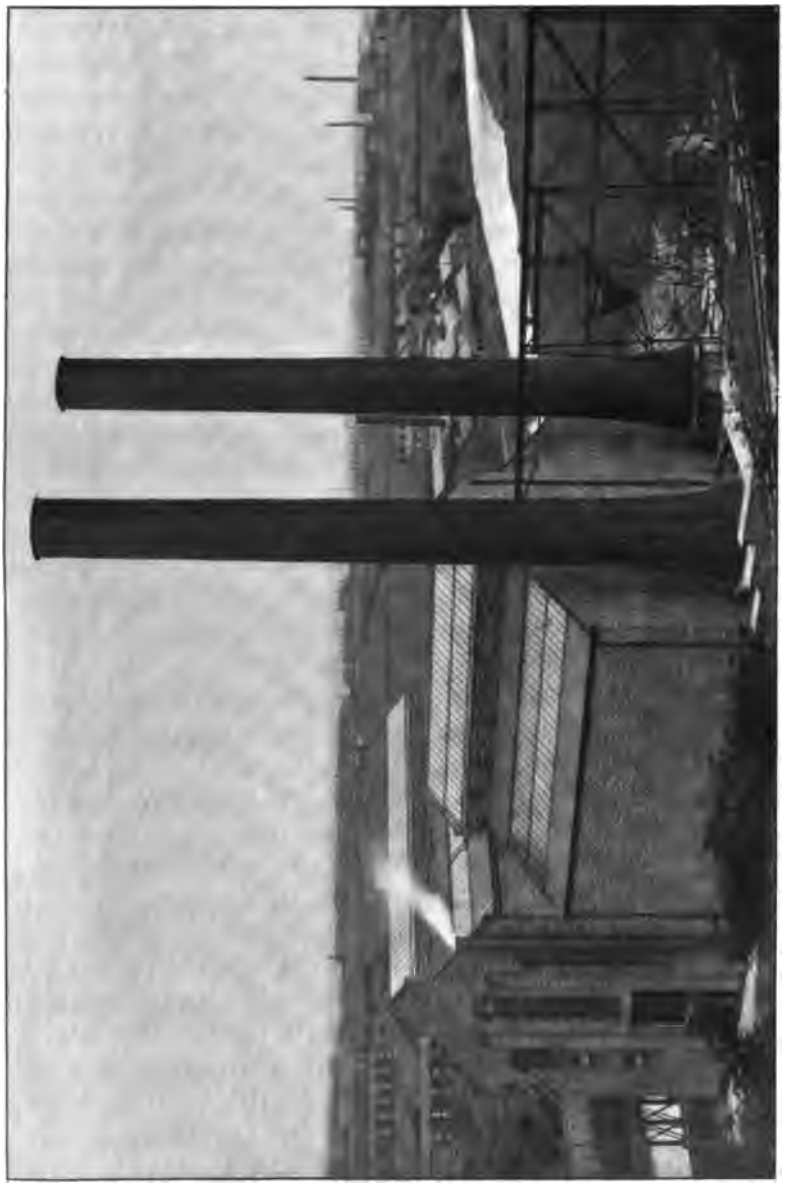

FIG. 1.—POWER-STATION AT RADCLIFFE.

The large power-companies aim at nothing less than the highest; they are working steadily, with the object of supplying

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all the power needed for all purposes. It is with this object before them that the designers and organizers have set out. In order to succeed in such an enterprize, it is clear that several things are necessary:—(1) The current must be as cheap as, or cheaper than, any other form of power; (2) the supply must be absolutely regular in pressure, etc.; and (3) the supply must be so constant that, but for a veritable "act of God," there cannot be a stoppage.

In order that the supply may be given cheaply, it is clear that the cost must be kept down at a minimum, and this is dependent on three things:—(*a*) Capital outlay; (*b*) working cost; and (*c*) the amount of work done.

(*a*) The small-supply concern, being generally bound to its own area, has little choice of site, and frequently it has to spend large sums on obtaining land, especially as the centre of a supply-district is generally taken, so as to minimize the copper spent on the mains; whereas the power-company can pick from a large area, and should be able to buy far more cheaply.

The town-supply, founded only for meeting the growing wants of its own little area, can put in but small plants. In so doing, it is at a great disadvantage compared with the power-company: for, not only is the price per kilowatt far more with the small plant, but the floor-space, and consequently the building area, is far in excess per kilowatt of that which is necessary for the power-company.

In the mains, also, there is a notable advantage to be credited to the power-company. The power-carrying capacity of a main of given copper-capacity varies as the pressure, but the drop in pressure varies in volts as the current. It must be borne in mind that the amount of electrical power is the product of the volts and amperes. The ordinary town-supply is 500 volts and that of the power-company 10,000 volts. Now, not considering the question of the supply being three-phase, but only the two voltages, a given cross-section of copper can carry a given quantity of current, and 20 times as much power will be transmitted along the same copper at 10,000 volts as at 500 volts; but the advantage does not end here. The important factor in voltage-drop is the percentage-loss, and not the actual number of volts. Now, with a certain current flowing in a

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main, the drop in volts increases as the distance, so that, if in a certain distance, the voltage-drop were 50, in the case of the 500 volts supply, the loss would be 10 per cent., while in the case of the 10,000 volts supply the loss would be 0·5 per cent.; or, in other words, the current could be sent 20 times the distance for the same percentage-loss, that is, 20 times the power could be transmitted 20 times the distance with the same copper-section, if the pressure were 10,000 instead of 500 volts. In order to utilize the high voltage, however, a more expensive switchgear has to be used, and the current has to be transformed down at the working end: therefore it would not pay to adopt the high voltage in a small area, as the money spent on switchgears and transformers would outweigh the saving in copper. A radius of 2 miles is about the economic limit for the ordinary supply at 500 volts; rather more can be managed for traction, as the voltage-variation is not so important.

Taking these points, and many other small ones, which it would be tedious to enumerate, the capital cost per kilowatt installed by a large power-company should be from 50 to 25 per cent. of the least at which an ordinary town-supply concern could arrive.

The capital cost has now been shown as being, in the nature of things, less than in the case of a small undertaking. The same arguments are true to a great extent with individual works: the only extras for the supply are the dynamo, switchgear and mains; in the individual works, the floor-space, the buildings and the chimney, cost more per horsepower installed, and the cost of the individual small sets is larger per horsepower than the equivalent in the power-house. Still, although, in many cases, the advantage can be shown well in favour of the power-company, it must be confessed that, in many others, the reverse may be true. Then, so far as low cost of energy is concerned, the other two factors must be relied on.

(*b*) The working cost comprizes chiefly coal, wages and management. Coal is naturally a very important item. The internal combustion-engine has been often quoted as the solution of the problem; if it does diminish the coal-bill, that is its only excuse for existence, for the economy of the up-to-date large turbine-set is so high, that under ordinary conditions even

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this diminution is not great. A really considerable saving can only be obtained by using the ammonia-recovery process, and selling the sulphate as a set-off to the coal-bill; but such a plant is not a very desirable adjunct to a 10,000 volts supply-station.

The arguments against the utilization of the gas-engine are chiefly constructional ones, the floor-space required for a 2,000 horsepower two-cycle gas-engine, without any auxiliary apparatus, being about 2,800 square feet; a Curtis turbine of the same capacity need only have 120 square feet, say, an area of 50 feet square as against 11 feet square; but 2,000 horsepower for a power-company is a smallish set, 8,000 horsepower being more like the useful standard size. No gas-engine of such a size has yet been constructed, and, if it were, it would be a horrible enormity. The time may come when the long-dreamed-of gas-turbine will become an accomplished fact; this will, of course, greatly change matters, and then steam may find a serious rival in the internal-combustion engine. Another objection to the gas-engine is that its angular velocity is not sufficiently constant, and, upon perfectly-even turning, a great deal of the utility of the modern power-company (especially in Lancashire) depends. The turbine, on the other hand, has an absolutely constant angular velocity. Further, experience has not yet demonstrated the reliability of a gas-engine exceeding 500 or 600 horsepower, and above all other things, it is essential that a power-company shall be reliable. The gas-plant has many peculiarities which are against its use: the repair-bill of the engine and of the producer is large, the huge size of a set entails a large staff to look after it, and the oil-bill in most cases is a very serious item. These and other considerations have made the designers of the power-companies fight shy of this method of reducing the coal-bill.

In the matter of coal, however, the power-company is in a better case than municipalities or private concerns. They can place their works at the pit-mouth, and avoid freight; they use larger units than could be required by other concerns, with a consequent higher efficiency; they can settle close to a good water-supply, which means a good vacuum, and also makes for economy; and their long hours of work minimize the stand-by losses. Owing also to the enormous amount of coal burned, the price is naturally "rock-bottom"; and the various conditions

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reduce this item of expenditure to such an extent that the coal-cost per horsepower-hour is lower than can be attained, either by the town-supply or by the individual works.

The wages-bill is far less also: in the case where turbines are used, one driver and one greaser per shift can attend to four

Fig. 2.—Boiler-house at Radcliffe.

machines, or 8,000 to 10,000 horsepower; whereas if this power were split up into 20 different concerns, at the very least twenty drivers and several cleaners would be needed; so also with the stokers, two men can look after the mechanical stokers needful

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to generate steam for this power, while at least 10 times this number would be needed in the other case. So also with the management: with huge concerns many times larger than the 10,000 horsepower plant abovementioned, the expenses under this head increase but little, whereas each little concern has to bear its own cost of management, and so the ratio becomes increasingly favourable to the power-company in actual production-costs.

(*c*) The third of the economic features of a power-company, and perhaps the most important, is the amount of work done, that is, the amount of units sold in relation to the greatest amount that could be sold if the whole plant were working at full load during the 8,760 hours of the year: this ratio is the load-factor of a concern. In electrical undertakings, the load-factor is calculated with the maximum demand on the station, instead of the total installed in the station. Taking this as a basis, the load-factor of a good town-supply ranges from 18 to 25 per cent., while the power-company would range from 45 to 60 per cent. In single industries, a mill ranges between 26 and 30 per cent., individual small ironworks range between 12 and 15 per cent., while tramways get as high as 23 per cent. It is difficult to say what the load-factor of a coal-mine would be, the circumstances of each mine being so different, depending on how much is done in each class of work (pumping, ventilating, hauling and winding): it might vary from 15 to 40 per cent.

The power-company should head the list, and one or two examples will make the matter clear. The ordinary town-supply in winter has a short period of heavy load from about 4·0 p.m. until 7·30 or 8·0 p.m. The coal-mine shuts down a good deal of the work at 4·0 p.m., so that when the demand for power ceases at the colliery, the lighting-load takes its place. Again, the load-factor of any one coal-mine may be 20 per cent., but the times of maximum would vary, with the result that the combined load-factor of three or four mines might be 30 per cent.

A great deal, however, can be done by the power-company to improve its load-factor. By the offer of a rebate, many consumers are glad to make small alterations in their working hours; a colliery can often manage to alter the hours of pumping so as to suit the power-company, for which the company can well afford to make a reduction.

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One case in actual working is of great interest. There is a large county-borough with a big central supply power-station, which works both lighting and tramways. This concern anticipated an extremely heavy tramway-load during Whit-week, and

FIG. 3.—TURBINE-HOUSE AT RADCLIFFE.

to meet this it had to instal a great deal of extra plant. Now, had this work been done by a power-company, the works which the power-company drive would be standing idle during the holidays, and in consequence the natural diversity would have

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helped to load up the plant that would otherwise have been slack owing to the holidays, and also would not have necessitated the spare plant which the county-borough had to instal. So, by natural differences in times of working in some cases, and assisted differences in others, the power-company can arrive at long working hours. And it is only the power-company that can get these results.

The areas of these great undertakings cover many hundreds of square miles. The Yorkshire Company has 1,800 and the Lancashire has 1,200 square miles. These large areas in industrial districts imply a great variety of power-users, with a considerable natural diversity of load. There are in the Lancashire district, for instance, collieries, quarries, cotton-mills, and all the allied trades, many of which can do work at night. There are also ironworks of all descriptions, and, besides these, the ordinary lighting and tramway-load is found in many townships. No such diversity can be hoped for by any mere town-supply. That this is of enormous importance, is shown by the fact that, in the case of one power-company, the horsepower of the motors installed amounted to four times that of the plant installed in the power-house. Thus, the power installed is only one quarter of the power required in the consumers' works, and the earning power of each horsepower of the power-company is far in excess of that of the individual user of machinery. It is, then, owing to this greater earning power, backed by the small labour and coal-charges, and helped by the small capital-cost, that the power-company can sell current at rates suitable to all.

Another important point is that the machinery, which the power-company drives for the consumer, should be turned at an absolutely constant speed. This is not so important in mines, perhaps, as in many other industries; still, it is an advantage in a colliery too. The curves showing the variation of the turning speed or the angular velocity of various classes of work are very interesting. Many works-managers will declare that the turning is perfect, yet when the recorder is put on very strange vagaries are seen, the regular changes at each period of the engine's stroke being often quite clearly shown. The power-company, with its great bank of turbines, alters all this. The turbine, having a constant inlet of steam, has a perfectly constant speed at all parts of the revolution, and being direct coupled to the

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dynamo, makes the latter rotate also with absolute constancy (the generator gives a three-phase current). Now, the speed of the three-phase motor depends on the periodicity, and, as this depends on the speed of the generator, which is constant, the motor speed also does not vary. This is so important that, in some industries, the output has been increased by 10 to 20 per cent.. on account of the change from the old driving methods. The small station, unfortunately, cannot reach this perfection, as the direct-current motor slows up with added load; and, as before explained, the small supply has to use direct current.

There must be no stop. Electricity taken from the modern power-company meets this condition better than any other known form of driving. It is only with concerns of really large size that it can be economical to utilize the best methods for assuring continuous supply; how this perfect safety is arrived at is dealt with later and more fully in the description of the station and of the methods of distribution. Briefly, each item of the plant is of the utmost perfection and simplicity: each section is independent, so that in case of a fault happening to one section, there is another ready to take its place; there are spares throughout; and the distributing switchboards are reduced down to the utmost simplicity. These have been in the past a fruitful source of breakdown, which is now happily removed. The mains also are in duplicate throughout, so that if a breakdown occurs on one route the other branch can be used. Scarcely any individual works possess any such stand-by plant, and, even in the best regulated works, a breakdown may occur. The power-companies do not expect to be immune from them, but all plant is so doubled that whatever happens there is the spare to take up the work.

These three necessary conditions, then, have been met by the power-companies; and, having accomplished that, they feel that success is assured.

The Lancashire Electric Power Company's station, at Radcliffe, is fairly typical, and a description of it may show how the advantages, which power-companies possess, have been made the most of.

The transmission at high pressures to long distances being so easy, the exact position of the station with respect to the load is not of such importance, consequently the best site

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economically can be obtained. The site (Fig. 1) at Outwood, near Radcliffe, has very great natural advantages. It is on the banks of the Irwell, consequently there is plenty of condensing water; it is beside the Lancashire and Yorkshire railway, whereby railway-facilities are secured; and it is close beside a colliery, so that coal at pit-mouth prices can be obtained. There is a siding from the railway, taken right on to the company's land, running at the back of the boiler-house.

At a position opposite the boiler-house, the siding passes over a hopper into which the coal is tipped. From a level, a few feet below the bottom of this hopper, there is a slightly inclined track running into the boiler-house at a height of some 25 feet above the firing-floor. Along this track runs a trolley, which is filled from the containing hopper, weighed, and conveyed by gravity to the boiler-house; and on its way it picks up a counterweight which, when the trolley is automatically unloaded, returns the truck to the hopper. The truck is emptied into bunkers arranged along the lines of boilers, and above them. The coal passes down through the bunkers into electrically-driven chain-grate stokers below the boilers. Thus the coal is not touched by hand from the pit-mouth to the fire. The six boilers, being a first instalment (three on each side), are of the Babcock-and-Wilcox water-tube type, each capable of evaporating 20,000 pounds of water per hour, from 60° Fahr. to steam at a pressure of 160 pounds per square inch, and 150° Fahr. of superheat. The main flues are beneath the boilers, and pass out to two brick-lined steel-chimneys behind the boiler-house. The two banks of boilers face one another, and the alleyway is at right angles to the engine-room length (Fig. 2). This arrangement admits of a minimum length of steam-main, and is so planned that extensions can be made with the utmost facility. A ring steam-main is fed by all the boilers, and is complete in the boiler-house. From this ring each engine is supplied. The auxiliary plant calls for no particular remark.

The engines are of the turbine-type, and of 2,000 kilowatts capacity each (Fig. 3). One bank of boilers feeds two turbines, and these form one unit of plant. In this case the turbines are of the vertical type, and have some advantages, the floor-space being very small and the construction very simple. It is not until a concern arrives at a considerable size that the turbine can be

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used effectively: it is generally considered that small machines are not so satisfactory, and certainly the larger the plant the greater is the advantage. The turbines drive direct on to

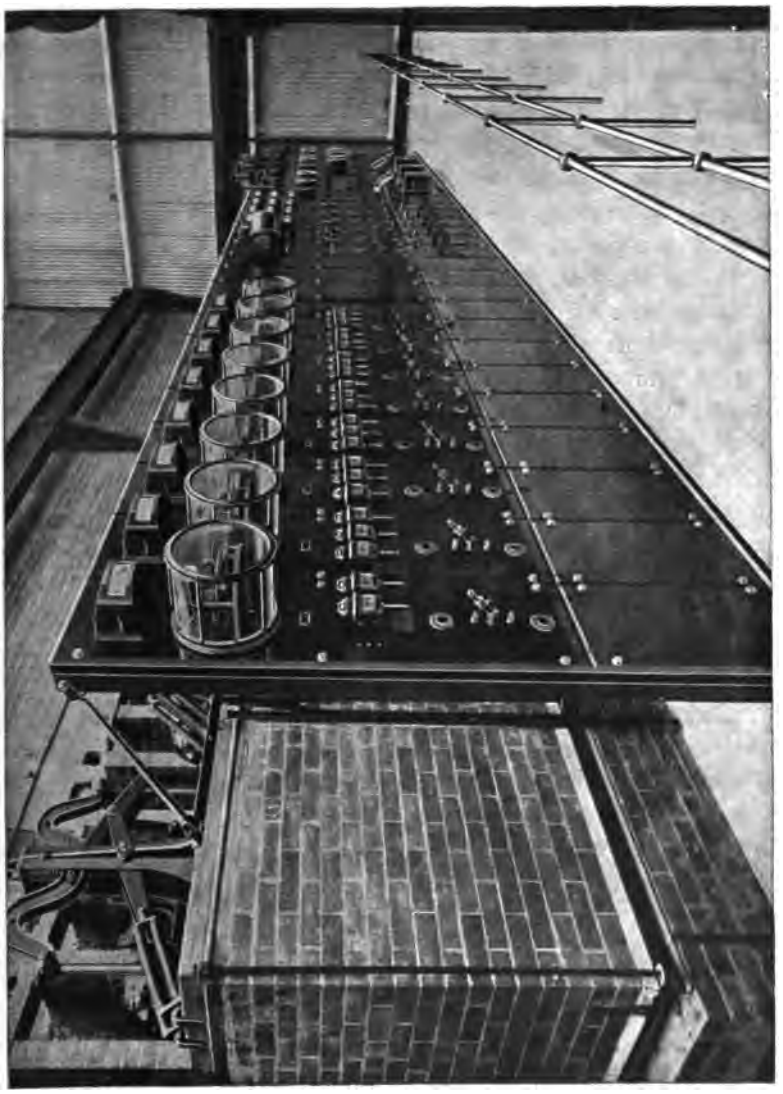

FIG. 4.—SWITCHBOARD GALLERY AT RADCLIFFE.

the three-phase 10,000 volts alternators, which are placed above them. The only point of power-company economics that affects the actual generating plant, besides the steady drive referred

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to before, is the fact that the cost per kilowatt is less for the large sizes employed by the power-company than for those used by the smaller concerns.

The three-phase current generated at the high pressure of 10,000 volts is carried to the switchboard (Fig. 4). A great deal depends upon the design of this section: the operation must be easy, there must be no danger from fire, and the whole must be safe. The system known as "remote control" has been employed almost universally. Remote control means that none of the main current is taken to the operating board: the main current being taken to large oil-switches, each of the three limbs being placed in a separate stone cell. The switch-contacts are operated by means of a small motor and strong springs, and only the small motor is started from the operating board. None of the instruments are on the main cables, all being operated by means of transformers, which give a suitable ratio for the reading of the instruments. The danger of switchboard-trouble is overcome; no mains of large power are on the operating board, so that there is nothing to catch fire; and, even if any little accident did happen, it would not damage the main cables, as they are not near, and the supply would not, therefore, suffer. The whole working of this board is so simple and automatic that, while being safety itself, it can be easily looked after by one man. From the switching apparatus, the current passes out on to the mains, still at a pressure of 10,000 volts.

The general design of the station is perhaps a most important one from the power-company point of view. Each section of the station is built up in units, one bank of boilers feeds one section of turbines, each with their own auxiliary plant; and each bank of turbines feeds one section of the switchboard. These are so arranged that, in the case of a failure in any one part, the spare section can be put in immediately, and the faulty one disconnected. This is true also of the main cables, as beforementioned. Facility of distribution at high pressure has already been mentioned, and it is made the most of.

The mains run straight from the station; in one case, they run right up to the north and along the Rossendale valley, where they tap quarries, slipper-works, and the cotton-industry. To the west, they run out past the south of Bolton into the Westhoughton and Wigan districts, and generally are antici-

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pated to serve the coal-district. Another main branch is run through Swinton, and it will serve the cotton-industry.

The loss in transmission is so small, that even at these great distances the combined main loss should not be more than 5 per cent. In many small town-concerns, this item reaches 10 and sometimes 15 per cent. The company serves either a township or the individual consumer; and, in the case of the Lancashire Power Company, this service is made on behalf of the township in which the consumer is located. In the case of serving a township, a small cheap sub-station is erected, and the ordinary distributing mains to supply small private users, both lighting and little motors, are laid down. By this means, the chief part of the working expenses and a great deal of the capital expense is saved for the township; and it is able to distribute to the consumers at a price which it could not hope to touch, if it had all the heavy burdens of capital-expenditure and wages to bear. In the case of the private consumer, the high-tension current is brought direct on to his premises, where a small sub-station of a few feet square is built, the current transformed down to a working pressure, and this is distributed through the works. The three-phase current being admirably suited for motor-work, only static transformers are needed, and consequently no superintendence is required for looking after the plant. The result is that current, generated under the most economical conditions possible at a central generating-station, whose capital-expenditure per effective horsepower is low, with very small transmission-loss, can be provided to the industries of the country, at as low a cost (nay, lower) than they could make it for themselves, giving them, at the same time, a power, which can always deal with very severe temporary overloads, which can ensure a perfectly even turning (and so prove of enormous value to any delicate operations), and which, at the same time, can secure immunity from any stoppage by means of the great simplicity of the system, combined with complete spares.

With these facilities, power-companies hope to become the practically universal providers of power for all purposes in the country. The reasons for the hope have been set forth; the future only can show whether these hopes will be fully realized.

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Mr. Sydney F. Walker (Bath) said that Mr. Gamlen claimed that electric-power companies could supply current at a cheaper rate than an industry could supply itself, but he ventured to controvert this opinion. Electric power-supply companies had, of course, great advantages in the large units that they were able to lay down, in the load-factor, and in the other points mentioned, such as erecting the station alongside a colliery, with water at hand, and so on; but in the case of iron-works or collieries, he (Mr. Walker) did not think it possible for any electric-power company to supply current at a lower cost than they could produce it themselves. The load-factor of coal-mines had not yet been thoroughly examined, but it depended on whether there was a heavy pump-load, and whether electricity could be used for winding. There was clear evidence that the cost of electrical winding was practically prohibitive in this country at the present time; and he understood that the winding-engine took practically 50 per cent. of the entire load of a colliery; the ventilating fan, 16 per cent.; and unless there was a big pump-load, there was not much left upon which to economize. There could be no saving by applying electric current to drive a ventilating fan, as a triple or quadruple expansion engine was an ideal motor for driving it: the fan was required to continuously produce a certain volume of air with a certain water-gauge, and, therefore, it could be driven by any engine that would generate power economically. The same argument would apply against the use of electricity to drive a big pump with a continuous load.

The Rev. G. M. Capell said that, in the adaptation of three-phase motors to fans, he had found great difficulty in reducing the speed, and at week-ends and holidays, it was necessary, in order to ventilate the mine, to keep the fan running at the single constant speed. He suggested the use of two fans, each driven by a tri-phase motor, the two fans working together at the same speed, so as to give the full quantity of air; but so arranged that one fan could be stopped and the other kept in operation. By this arrangement, either fan, working singly, would produce about 80 per cent. of the volume at about 60 per cent. of water-gauge of the two fans working together, the speed being constant throughout. This arrangement would have an import-

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ant bearing on the question of economy; for, when the full volume of air was not required, the ventilation could still be maintained by one fan driven by a motor using half the power that would be expended on the two fans used conjointly under ordinary conditions or where one large fan was used.

Mr. C. C. LEACH said that cheap coal did not altogether depend upon the power-station being placed close to a colliery, because pit-prices depended on competition, and if the cost of carriage by road or rail from an adjacent colliery was 1s. a ton, the cost of the supply to the power-station would not unreasonably be increased by 10d. or 11d. per ton.

The PRESIDENT (Sir Lees Knowles, Bart.) proposed a vote of thanks to Mr. Gamlen for his interesting paper.

Mr. W. SAINT seconded the resolution, which was cordially adopted.

Mr. B. H. THWAITE'S paper, "Can Explosions in Coal-mines, with their associated Toxic Fatalities, be prevented," was read as follows:—

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CAN EXPLOSIONS IN COAL-MINES, WITH THEIR ASSOCIATED TOXIC FATALITIES, BE PREVENTED?

By B. H. THWAITE.

Public Opinion and Colliery-explosions.—The disastrous explosion at the Cambrian collieries in the Clydach Vale, South Wales, produced a painful sensation throughout the country, accompanied by an impression in the public mind, represented by the protest made in the House of Commons by a wellknown member, inferring that sufficient precautions, scientific or otherwise, were not taken to prevent these explosions, or, at least, to secure miners from being killed by them.

A Century of Attempts to secure Immunity from Explosions.—Almost a century has elapsed since Dr. W. R. Clanny and Sir Humphrey Davy introduced lamps bearing their names, to secure the safety of coal-workers; and research and invention have ever since been continuously devoted to discovering means for preventing colliery-explosions, yet still explosions occur. This fact prompts the question that constitutes the headline to this paper. One is almost justified in promptly replying to the question by a direct negative. The law of chance will intervene, and however perfect the precautions may be in theory, the absolute prevention of explosions in the workings, of the marsh gas exuding from carbonaceous strata, will never be possible.

The Proportion of Deaths from Toxic Effects will be Reduced.—But, in the depressing gloom surrounding this fact, there is a bright gleam of light. It will be possible in the future to ; revent the death of probably, say, 8 out of 10 men who die through the toxic influence of carbon monoxide, produced by the partial oxidation of coal-dust ignited by the explosive combustion of the marsh gas.

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Thanks to the masterly investigations of Dr. John S. Haldane and his collaborators, and to their diagnosis of the influences that have proved fatal or injurious to the victims of coal-mine explosions, we know the cause of the fatal sting of these accidents; and it is now possible to devise practical methods by which the deadliness of colliery-explosions may be reduced down to a mere fraction of their present magnitude.

The Genesis of Coal-mine Explosions and their Toxic Associations.—The raising of the veil of mystery, exposing the simple truth of the cause of from 75 to 92 per cent. of the deaths associated with colliery-explosions, has prompted new investigations and exposed remarkable features in the hygienic environment of coal-mine workers. To understand this, it is advisable to analyse the genesis of coal-mine explosions and their toxic association:—

1. Carbonaceous and indeed nearly all geological strata, other than those of an igneous character, are porous.

2. These pores in solid carbonaceous strata are filled with a combustible gas, known in colliery technology as marsh gas.

3. These strata are, by the course of coal-mine operations, pierced with workings, and the marsh gas is thus provided with an outlet of escape.

4. When the atmospheric pressure in these workings falls rapidly to a low level, then the resistance to the exudation of the marsh gas from the carbonaceous strata is reduced, and the gas flows into the workings more freely, and in greater volume.*

5. The marsh gas diffuses into the air of the workings, and when it has attained a volumetric proportion of 5 per cent. of marsh gas to 95 per cent. of air, the mixture becomes in a minor degree explosive: the maximum degree requiring 9·47 per cent. of marsh gas to 90·53 per cent. of air.

6. The presence of a bright-red incandescent igniting agent will fire the explosive mixture of marsh gas and air.

7. Assuming that such an ignition-agent exists, either as a spark or as a flame, the explosion in a Clanny lamp, the breaking

* Applied science may yet contrive a well-guarded barograph, so arranged that it will automatically and audibly signal in the working-zone of a coal-mine, when the atmospheric pressure falls rapidly to a danger-level. Such an apparatus, strongly built, might be equipped so as to give audible signals when the barometric pressure suddenly falls to a dangerous extent.

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of an electric incandescent lamp-globe, except when it is guarded with an independent (air or water) annular chamber,* the spark from the commutator of an electric motor or that from a pick-stroke, the flash from an exploded cartridge, the fusing of an electric conductor, or the breaking of a Davy lamp, will bring about an explosion and consequent gaseous expansion in the ambient zone, and any miners in the neighbourhood of the explosion may suffer from the shock of the impact of the expanded gases and be fatally injured either externally or internally.

8. The expanded gases momentarily increase the density of the air in the mine-workings along which the flame passes. The high velocity of the gases, *plus* the actual pressure due to their expansion, not only increases the density of the air in front of the flame and through which it diffuses,† but the density of the mass of suspended coal-dust, to which is added the dust swept into suspension by the flame from the roof, floor, sides and timbering of the workings, is greatly increased.

9. The result is the almost instantaneous ignition (by the marsh-gas flame) of this suspended coal-dust, and the marsh-gas *plus* coal-dust flame is thus extended until it dies out through the exhaustion of the air, deficiency of coal-dust, change of direction of workings, or the cooling influences of the side-walls.

10. The gases on cooling and contracting, immediately flow back to the source of ignition of the flame and become reheated by the effect of the stored heat in the partially burnt timbering, etc.; and this backward and forward movement adds to the danger of the toxic effects.

11. Coal-dust is in daily use as a fuel for furnace and steam-raising purposes, but its possible effect in extending the area of destruction of a marsh-gas flame was probably first noticed by Michael Faraday, in his youth the assistant and collaborator of Sir Humphrey Davy.

* It is tolerably certain that science and invention will ultimately be able to provide a practicable coal-mine illuminant, which under no conceivable circumstances will ignite a marsh gas and air explosive mixture. We have the basis of such an illuminant in the fact that the brush-discharge of static electricity fails to ignite the most sensitively-explosive mixture; and mercury-vapour or some adaptation of the luminous vacuum-tube may provide the principle of such a desirable and cold illuminant, that will be as incapable of effecting the ignition of marsh gas as is a glowworm.

† The most effective ventilation, as proved by the recent explosion at the Cambrian colliery, fails to remove the danger associated with the presence of marsh gas and coal-dust, even when the coal has a comparatively low proportion of hydrocarbons in its constitution.

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12. Prof. W. Galloway has, long ago, proved that the marsh-gas flame is propagated along the workings by coal-dust: the flames travelling along the dusty haulage-roads, which actually contain no trace of the presence of marsh gas.

13. This coal-dust extension of the marsh-gas flame is the principal source of that gaseous element which Dr. Haldane has placed on the highest pedestal as the prime cause of 75 to 92 per cent. of all the deaths resulting from an ordinary coal-mine explosion. This element is carbon monoxide, the highly toxic character of which is now becoming generally recognized.*

14. It is fairly certain that carbon monoxide is not produced in mine explosions by the combustion of marsh gas. The ordinary formula for this reaction is represented by $CH_4+2O_2=CO_2+2H_2O$; but the partial oxidation of coal-dust, and even the smouldering timbering of the workings, will produce the toxic gas, thus:—(*a*) $C+O_2=CO_2$; and (*b*) $CO_2+C=2CO$.

15. We can now realize that marsh gas is the igniting-agent of the toxic gas-producer (coal-dust); therefore (neglecting the small proportion produced by the smouldering timber), if this coal-dust were removed from the workings as fast as it is produced, then the toxic dangers to life associated with marsh-gas explosions in coal-mines (dangers which, as we know, are responsible for from 75 to 92 per cent. of the fatalities) would be eliminated.

16. *Coal-dust the Source of the Toxic Danger.*—The famous colliery-expert, John Buddle, as far back as 1813, realized that the major part (he gives the figure as 75 per cent.) of the deaths in colliery-explosions were due to suffocating effects, as distinct from those due to violence.

* The importance of determining the chemical change in the character of the products of the combustion of an explosive mixture of marsh gas and air, and that resulting from the sequential combustion, complete or partial, of coal-dust, will be recognized. The Government would be well advised in appointing a commission of experts to carry out a series of experiments, using, say, an abandoned mine as the scene of the practical determinations, in which coal-dust containing varying proportions of volatile hydrocarbons and of varying conditions of dryness could be laid on the walls, roof, floor and timberings, in as nearly like actual conditions as possible. An explosive mixture of marsh gas and air could be stored in an elastic container, and could be electrically fired at a safe distance. Automatic gas-containers could be located at fixed positions along the line of dust-flame propagation, and so contrived as to catch samples of the products of combustion for subsequent analysis. Such a series of tests would provide valuable indices of the character of the products of combustion and the nature and origin of the flame producing it, and would therefore permit of the origin of the carbon monoxide being carefully traced.

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17. In the Tylerstown explosion, 1896, the ratio of fatalities through violence equalled 9·2 per cent., the remainder of the victims succumbing to the toxic influence of carbon-monoxide inhalation (there being 5 deaths by violence, and 51 deaths due to carbon-monoxide toxic effects). The highly toxic (poisonous) character of carbon monoxide will be understood on referring to Table I., taken from the author's paper on "Accidents due to the Asphyxiation of Blast-furnace Workmen."*

TABLE I.—TOXIC EFFECTS OF CARBON MONOXIDE.

Carbon Monoxide in Air. Per Cent.	Time Required to Produce Dangerous Toxic Effects. Hours.	Minutes.	Carbon Monoxide in Air. Per Cent.	Time Required to Produce Dangerous Toxic Effects. Hours.	Minutes.
0·1	2	0	0.6	0	20
0·2	1	0	0·7	0	17
0·3	0	40	0·8	0	15
0·4	0	30	0·9	0	13
0·5	0	24	1·0	0	12

18. It must be obvious that were the coal-dust removed from the workings as fast as produced, and this is quite feasible as will be explained, the deadly virus of coal-mine explosions would be extirpated.

19. It is a remarkable fact that, although coal-dust is the source of the production of the toxic element or carbon monoxide, this same dust is considered to be the true explanation of the comparative immunity of coal-workers from the deadly effects of phthisis.

20. The author, in his investigations in 1880 into the effects of the dust-environment on the health of operatives in various industrial occupations, accepted the accuracy of Dr. Hirts' figures published in 1873 in his work on *Die Krankheiten der Arbeiter*, and tabulated in the author's work on the *Factories and Warehouses: Sanitary and Fire-resisting Arrangements*, published in 1881.

21. The tabulated results show that coal-miners are practically free from dangerous pulmonary diseases, and that charcoal-burners and chimney-sweeps are less liable to phthisis than the workers of all other industries in which dust is produced, and even less than workers in agricultural occupations.

22. *A Coal-dust Environment reduces the Proportion of Coal-miners' Deaths from Phthisis Influences.*—There is little question

* *Journal of the Iron and Steel Institute*, 1905, vol. lxvii., page 395.

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but that this remarkable immunity from phthisis is due to the antiseptic effect of the inhalation into the lungs of finely-divided coal (or carbonaceous) dust.

23. This remarkable fact is practically confirmed by the evidence, published by the Government, giving the comparative mortality-proportions from the disease of phthisis in different dust-producing mining operations. Table II. clearly shows the comparison to be strikingly in favour of coal-mine operations.

TABLE II.—THE MORTALITY FROM PHTHISIS OF MINERS, COMPARED WITH ALL OTHER OCCUPATIONS, BETWEEN THE AGES OF 20 AND 55 YEARS.

Tin-miners	65·0 per thousand.	
Lead-miners	30·3	,,
Average of all other occupations ...	20·8	,,
Coal-miners	15·4	,,

If those coal-miners, who contract the disease from the deficient ventilation of their homes, were eliminated, the proportion would be still less.

24. The question naturally arises, as to whether the reduction of the proportion of toxic fatalities associated with coal-mining operations, as a result of marsh-gas explosions *plus* coal-dust flame, would be more than counterbalanced by the increase in the number of deaths of coal-miners by the deadly phthisis disease owing to the removal of the antiseptic coal-dust environment.

25. *Coal-dust or no Coal-dust: the Balance of Evil.*—A simple calculation will show, even if we assume that the proportion of coal-miners' deaths from phthisis were increased to that representing the average level of all industrial occupations, that the annual increase in the mortality for each group of 100,000 coal-miners would be no less than 540 men, and in the most effective labour-period limits of 20 to 55 years. This simple figure alone is obviously very much greater than the deaths caused by the toxic evils associated with colliery explosions.

26. *A Partial Removal of the Coal-dust may prove the Best Solution.*—Direct experience will alone determine absolutely how far it is possible to remove the coal-dust without detriment to the healthfulness of coal-miners, and the author suggests that the Government might initiate such an investigation.

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27. But, assuming that the coal-dust environment of the coal-miner were permitted to remain as it is, will it be possible to prevent or reduce the deaths from toxic effects?

28. *The Oxygen Toxic Antidote.*—An affirmative answer may at once be given, and for the following reason:—

It is generally known that oxygen is the best antidote for the toxic influence of carbon monoxide. Of course, pure air expels carbon monoxide from the hæmoglobin of blood, but pure oxygen will do the work five times more rapidly.*

29. *The Supply of Oxygen automatically turned on by the Effect of the Explosion.*—Now, if a supply of this vitalizing agent (oxygen) could be established along the line of working operations in a coal-mine, and in such a way that it would automatically escape whenever an explosion of marsh gas occurred, and through nozzles and at different points along which the flame was propagated, setting up at the same time whistling or other audible sounds, so that even in the darkness, which always succeeds an explosion, the victims would readily be able to find their way by creeping or walking to the nozzles of escaping oxygen, the flow of which would continue as long as was required to permit the rescue-party to find the victims and remove them, a duty that would be easily performed, because the location of the danger-zone would be sharply defined by the whistling noise of the escaping oxygen.

30. Assuming that such an automatic and sustained supply of the vitalizing fluid is established in a gassy coal-mine, it is reasonable to imagine that the great majority of the victims, unless crushed by falling timbers, coal, stone or earth, would be rescued from the extreme penalty of toxicity or death. Such a method constitutes the basis of a recent invention, the details of which the author proposes to lay before the members on a future occasion.

* Dr. J. S. Haldane, in his report on the Tylerstown colliery-explosion, made the following statement:—"The blood of a man will take up about 2 pints (1·1 litres) of carbon monoxide or oxygen. Hence, about 1 pint of carbon monoxide must be absorbed to produce half-saturation of the blood. Now, a man at rest breathes about 10 or 12 pints of air in a minute, and experiment shows that of the carbon monoxide inhaled about 60 per cent. is absorbed. Supposing, therefore, that the air contained 0·1 per cent. of carbon monoxide, he would absorb about 0·007 pint per minute. It would thus take him nearly 2¼ hours to absorb a whole pint."

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31. It will be readily acknowledged that such a supply of oxygen, or even the automatic tapping of the compressed air from a drill-hose, would take away much of the sting of death of many colliery-explosions; and the necessity of removing the dust will correspond with the proved utility of such a toxic antidote.* But, assuming that it is ultimately decided to remove the coal-dust from all coal-workings, this operation can be easily performed by the application of the mine-dust removal apparatus which is briefly described in the Appendix.

32. *Apparatus to secure the Removal of the Coal-dust.*—The success of this system for removing the dust and gases resulting from blasting operations in metalliferous mines proved its perfect applicability for the purpose of removing the coal-dust in mine-workings, whether the dust is deposited on the floor, roof, timbering or side-walls, or is suspended in the air of the mine-working.

33. Prof. Arnold Lupton, in a letter to the author, strongly suggested the service of this apparatus in coal-mines, because of its portable character and its possible association with the air-compressing gear of the drills, the air-pressure of which can be used not only for driving the suction-fan but also for disturbing dust-deposits for which the suction-mounting is inapplicable. The separation of the dust and certain noxious gases is effected by the principle adopted in the author's method of purifying blast-furnace gas. The mine-air would not only be separated from its suspended constituent, but it would be introduced into the workings in a slightly moist and comparatively pure condition.

34. The method of damping the coal-dust by water-sprinkling will obviously tend to reduce the proportion of dust that would be blown into suspension by the effect of an explosion; but unfortunately the presence of accumulations of water on the floors of workings has been known to introduce the danger of ankylostomiasis, and liability to contract rheumatic ailments is also known to be associated with the presence of water. Of course, the ventilating air in gassy mines could be moistened after the fashion adopted in factory-ventilation, examples of

* The perfection of portable oxygen-containers, available as they are at reasonable cost, makes the deficiency of such a provision for a rescue-party in any coal-mine an unpardonable omission.

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which can be found in the author's book on *Factory Sanitation*. The system of mine-air purification, described in the Appendix, will obviously tend to moisten the air.

35. *Conclusion.*—The writer may now summarize the advantages and disadvantages of permitting the dust to remain as at present, but with a complete oxygen-supply equipment; the dry system of removing the coal-dust; and the water-sprinkling system of settling the dust:—

(I.) Dry system of removal:—

Advantages: the reduction of the extent of the flame-propagation through the influence of the presence of coal-dust, and the lessened danger of asphyxiation by carbon monoxide.

Disadvantage: liability of increase in the proportion of miners' deaths from phthisis.

(II.) Use of water-sprinkling for settling the dust:—

Advantages: the reduction of the extent of the marsh-gas and coal-dust flame-propagation, and, consequently, lessened danger of asphyxiation or toxic effects.

Disadvantages: liability of increase of miners' deaths from phthisis; and miners may contract ankylostomiasis and rheumatic ailments.

(III.) Allowing dust to remain as it is, but providing a complete equipment for oxygen-supply:—

Advantages: reduction in the proportion of deaths from toxic effects; mortality from phthisis not increased; and no danger of contracting ankylostomiasis or rheumatic ailments, in addition to present liabilities.

Disadvantages: no decrease in the flame from explosion due to the presence of the coal-dust; and the miners are still subject to danger from the inhalation of carbon monoxide.

36. The author trusts that this brief review of the conditions that on the one hand endanger, and on the other hand safeguard, the life of a coal-miner may be accurately balanced; and that the weight of evidence in the direction of precautionary reform will bear effective and early fruit for the benefit of the workers in the great and national industry of coal-getting.

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APPENDIX.—Description of Coal and other Mine-dust Removal-apparatus.

British patent, 1904, *No.* 13,594. *Improvements in Apparatus for Dealing with Dust in Mines and the like.* Messrs. B. H. Thwaite, T. J. Denny and R. E. Commans. This invention relates to an improved method of separating from the air of mines in or near the working-face, the siliceous and other mineral and carbonaceous dust resulting from the drilling and ore-getting operations, as well as the objectionable elements of the productions of combustion of the high explosives used in mining operations.

The air is collected by powerful suction from as near the points of emission of the dust from the drill-hole as possible, the collecting pipes being so devised as to allow them to be rapidly applied by screw-adjustments to any position at the face or across the drive, with as little interference with working operations as practicable. The dust-laden-air collecting pipe is perforated on its under side, and may be provided with sliding sleeves to cut off some of the perforations; or the perforated pipe may be bent, so that it will more effectively remove the air from the locality of emission or of production. This portable dust-collecting pipe is made of suitable metal, light but rigid, and not easily damageable by falling rock or explosive effects. At the end of the collecting pipe, a branch-swivel or other rapidly-applied attachment is provided, so that a flexible pipe, such as an armoured hose, can be easily connected to it in such a way as not to obstruct working arrangements.

The armoured hose delivers the dust- and gas-charged air to the portable purifying apparatus, which consists essentially of three elements:—(1) the washer; (2) the compound fan or suction-apparatus; and (3) a slag-wool or sawdust filter. The washer consists of a vessel containing water, or water to which quicklime has been added, and to which a disinfectant or deodorizer can also be added. By an arrangement of partition-plates and baffle-plates (either straight or circular, depending upon the shape of the vessel, and from which are suspended perforated plates or wire-netting or gauze, with the object of compelling the air-flow to be of uniform character), the air is compelled to flow repeatedly through the water, and several times in succession. If the water is charged with quicklime, the carbon dioxide present in the air will be immediately absorbed, and if the water contain a disinfectant any germs carried with the air will be attacked.

After being drawn through the washing or water-filtering apparatus, the air enters the compound fan, which may also in certain applications be equipped with water-jet pipes, to assist in separating the dust by centrifugal effect. The fan is of the enclosed type, and is so constructed as to establish easily a suction-effect equivalent to a head of several inches of water. In order to enable the water, separated by the effect of centrifugal action, to flow from the fan into the washer, the fan may be placed at such an elevation as to permit of this. The purified air, in flowing from the fan, enters an armoured hose-pipe, conveying it to a distributing pipe, which, like the collecting one, is easily fixed to secure the best results, the air, of course, being delivered as near where the men are working as is practicable. For special applications, a slag-wool or wood-wool filter may be added, through which the air is forced by the fan.

Fig. 1 (Plate X.) shows the general arrangement of the apparatus in its application to a drift in a mine, in which drilling and blasting operations are being performed. The dust from the different drills is drawn away by the sucker-hood or terminal, A, held in position by the supporting and adjust-

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able crutch, B. The dust is sucked through the branch-pipes, D, which are preferably armoured. The particles of dust that may be sucked into the hood, A, are carried along for some distance until they reach the coupling, E, which can be rapidly disconnected. The dust is sucked forward to the dust-collector, F, by the powerful aspiratory influence of the centrifugal fan, G. The dust-collector, F, described in greater detail in Fig. 2, is placed in a cavity, or in any other position removed from a point of interference in the active operations of drilling, blasting and transportation. A perforated pipe, H, spans the drift near the zone of drilling operations, so that when blasting is being carried on, the suction-effect of the centrifugal fan, G, connected to the cross-pipe, H, rapidly clears away the products of the blasting operations. The products of combustion are forced through the absorbing and cleansing fluid in the collector-vessel, F. One main pipe, C, is available for several drills and cross-pipe requirements.

Fig. 2 (Plate X.) represents a longitudinal section of the dust-collector vessel, with its associated centrifugal fan and electric motor for driving the same. The dust-collector, F, consists of a rectangular vessel, containing the absorbent and filtration-liquid, the level of which is maintained at *a*. Through this liquid, the gases and the air carrying the dust in suspension are forced to flow in thin streams, because the volume of air is broken up by the hanging perforated plates or wire-gauze frames, *b*. Other plates, *c*, divert the flow of the air. The dust-collector, F, is equipped with a liquid-seal compartment, *d*, formed by means of a sloped or inclined plate, *e*. This arrangement enables the miners to notice the height, muddiness and colour of the liquid; it allows of new absorbents, or other chemical agents, as well as water, being added, and the deposited dust can be raked out of the vessel without stopping its operation. The dust-collector, F, is fitted with flanged wheels, *f*, so that it can be run on the mine tram-rails, *h*. It is placed on a framed mobile-carriage, *i*, that carries the centrifugal fan, G, and its electric motor, I. The dust-collector, F, may, moreover, be so arranged in relation to its carriage, *i*, that it can be tilted in such a way as to reduce the depth or degree of the hydraulic seals formed by the partitions, *b* and *c*: that is, when the apparatus is being used for the removal of the products of combustion after blasting operations. The carriage-frame, *i*, is mounted on rollers. The pipe-connections, *j*, deliver the air, gases and dust into the collector-vessel, F, and the cleansed air passes into the fan by the pipe-connection, *k*. The arrows indicate the direction of the flow of the air and the dust, which it contains in suspension.

Fig. 3 (Plate X.) is a detailed plan of the sucker-hood or terminal, by which the dust is drawn into the hose from the drill-holes. The sucker-terminal, A, (Fig. 1, Plate X.) is made of light sheet-steel or aluminium. When special suction-effects are required, an elastic collar, *o*, made of spongy indiarubber, is provided. The suction-effect is applied by the annular orifice of the collar, *o*. This sucker-hood surrounds the drill-bar, *m*; a gap allows of the sucker-hood being readily applied, but, of course, the sucker or hood may be made completely circular. The elastic collar, *o*, is riveted to the plate-sides of the annular grove or trough, *p*.

Fig. 4 (Plate X.) shows the special kind of air-main coupling that may be used to retain such particles of stone or pebbles as may have been sucked into the air-main. This coupling can be readily disconnected, and a coarse wire-gauze screen, *q*, may be placed across the coupling-area.

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Mr. Charles Pilkington said that, so far as the removal of coal-dust was concerned, it would, if possible, be better to prevent its accumulation in large quantities. At the Pendlebury collieries, the coal produced a large amount of dust; but, as steel-tubs were used that did not leak, the bulk of the dust, which would otherwise have been deposited on the roads of the mine, was taken to bank. There were always objections to every scientific invention that had been brought out, and he suggested that the liberation of oxygen might tend to produce fires, with disastrous results.

Mr. Henry Hall (H.M. Inspector of Mines) said that the author suggested that the toxic effects of an explosion could be obviated by providing a system of pipes containing oxygen. In the event of an explosion, however, these pipes would be destroyed, and the oxygen would all be lost at one point and not distributed throughout the workings as the author imagined. As regarded the dust, he would encourage Mr. Thwaite to this extent, that there was not the slightest chance of introducing any system that would reduce the dust to such a degree that it would cause miners to suffer from phthisis. The removal of dust was a difficult operation; and if the writer suggested a dust-collector, similar to that employed to clean houses, he would recommend him to visit a dusty coal-mine, and he would then realize that no appliance of that kind could possibly remove the accumulated volumes of dust.

Mr. W. H. Coleman said that carbon monoxide could only be produced from carbon dioxide by reduction by coal-dust at a temperature considerably higher than would be found in a coal-mine. Possibly it might be formed from marsh gas or fire-damp, when an explosion was nearly finished and the proportion of the air was diminished. He did not think that the removal of the coal-dust would decrease the production of carbon monoxide.

Mr. W. N. Atkinson (H.M. Inspector of Mines) said that it had been proved that carbon monoxide was formed by the ignition of coal-dust in the complete absence of fire-damp. With reference to Mr. Thwaite's proposal to take oxygen in pipes into the mine for use after an explosion, it was extraordinary how great a fascination a series of pipes seemed to have for persons

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not intimately acquainted with the working of mines. He thought that the general lack of success of all such schemes did not say much for the equipment for the supply of oxygen; but he thought that the apparatus for removing the dust by pneumatic means was well worthy of investigation. Despite the immense amount of dust on a colliery-road, it was only a matter of providing sufficient tubs for its removal, if it could be collected and drawn into them; it was simply a question of the apparatus, and whether it could be applied on a large enough scale. An apparatus that would clean a road absolutely, by removing all the dust, would be of the greatest use.

Mr. C. C. LEACH said that the cost of removing the dust by such an appliance would be considerable; and if the cost of carpet-cleaning was any criterion, the cost of the removal of dust from a coal-mine would be prohibitive.

Prof. HENRY LOUIS believed that the views of the previous speakers were practically correct, and that coal-dust, burned with an insufficient supply of air, would produce carbon monoxide; but, the reaction indicated by the second equation* could not occur at the temperature ordinarily obtainable in colliery-explosions. He agreed with Mr. Hall that the pipes, containing the oxygen, would be wrecked by an explosion, and the survivors would see a fine exhibition of fireworks. With regard to the question as to whether coal-dust prevented phthisis or not, there was surely something more to be said. A comparison had been drawn of the small amount of phthisis among coal-miners as compared with metal-miners; but the conditions of working were very different, quite apart from the fact that the coal-miner was wound up from his work in a cage, while the metal-miner had frequently to climb a considerable length of ladders in shafts, which in itself was proved to have a very serious effect. In any case, the cost of Mr. Thwaite's appliances would be prohibitive.

Mr. J. S. MARTIN (H.M. Inspector of Mines) said that the proposal to carry oxygen in pipes into the mine reminded him of a similar suggestion that had been made for the erection of refuge-holes, which were to be supplied with fresh air by means of pipes. This arrangement had been adopted in one mine, and

* *Trans. Inst. M. E.*, 1905, vol. xxx., page 391.

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on one occasion, when visitors were shown the arrangement, it was found that the refuge-hole, fitted with doors, etc. (where the miners were to go for safety after an explosion) was full of fire-damp: it had been erected over the orifice of a blower of gas. He was afraid that the use of pipes, in the way suggested, would not be practicable. He asked, with regard to the supply of oxygen, whether Mr. Thwaite had calculated the quantity that would have to be supplied, and the cost of the apparatus required to provide the necessary quantity.

Dr. F. C. GARRETT (Armstrong College) wrote that Mr. Thwaite's statement that "It is fairly certain that carbon monoxide is not produced in mine explosions by the combustion of marsh gas"* required qualification. More than a century ago, John Dalton found that when marsh gas was exploded with its own volume of oxygen (half the amount required for complete combustion), it gave equal volumes of steam, carbon monoxide and hydrogen; and his results have been confirmed by Messrs. Kersten, E. von Meyer, J. W. Thomas and others.† Mr. Thwaite appeared to suggest that, after an explosion, oxygen should be admitted into the workings in sufficient quantity to enrich the air, and that this supply should be kept up "as long as was required to permit the rescue-party to find the victims and remove them";‡ this would, of course, necessitate the blowing in of enormous volumes of oxygen, and would very greatly increase the risk of fire.

Mr. M. H. HABERSHON wrote that it would be impossible to reproduce experimentally the dust-conditions existing in many coal-mines. He thought that any series of experiments, such as were suggested by the writer of the paper, would be of no practical value at the present time. The explosive nature of coal-dust was fully recognized. The danger was a very real one; its causes and the possible methods of removal had been recently summarized in an admirable paper by Mr. W. H. Pickering, H.M. inspector of mines (India).§ The administration of oxygen was doubtless the best method of dealing with carbon-

* *Trans. Inst. M. E.*, 1905, vol. xxx., page 391.

† The subject was discussed in *A Treatise on Coal, Mine-gases and Ventilation*, by Mr. J. W. Thomas, London, 1878, pages 154 and 323.

‡ *Trans. Inst. M. E.*, 1905, vol. xxx., page 394.

§ *Ibid.*,1905, vol. xxix., page 134.

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monoxide poisoning, but any suggestion involving the laying of pipes along the roadways of a mine for this purpose could only be considered as impracticable. He thought that the loss of life, from this cause, in mines, could only be reduced by training men in the use of the pneumatophore; as by this means oxygen might be administered, and lives saved. The pneumatophore was gradually being improved, and in its present form was a very different apparatus from that originally tried in this country. He thought that suitable men, thoroughly trained, would be found capable of accomplishing far more in the work of exploration, rescue and restoration of a mine, than was generally thought possible by those unfamiliar with the latest type of this apparatus. It would, however, be useless to provide apparatus without taking steps to keep it always in the most perfect order and having men at hand thoroughly trained and in practice. He thought that the establishment, by groups of neighbouring collieries, of central stations with this object, would be found preferable to individual effort; and that there was no subject at the present time more deserving of the consideration of The Institution of Mining Engineers.

Mr. H. Richardson Hewitt (H.M. Inspector of Mines) wrote that Mr. Thwaite's paper was of a somewhat remarkable and unusual character, and appeared to imply that the remedy for explosions of fire-damp in mines was quite simple. There could be no doubt that coal-dust played a great part in explosions, and even if it were possible to clear all roadways of dust during one day, sufficient would be made during the next twenty-four hours to render the continuation and extension of a fire-damp explosion possible, assuming that coal had been conveyed along the roads. It was not the huge amount of dust lying on the floor which was immediately dangerous, but the extremely fine particles which were floating in the atmosphere of the mine, and gave an underground traveller a black face without his appreciating the fact from his own feelings. The dust on the floor only served as a creator of the fine particles by the disintegration which it was undergoing from the traffic passing along. The proposed apparatus for removing dust seemed to apply only to the particles caused by the boring of shot-holes, which were of no importance whatever in a coal-mine; but not to the dust

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caused by the conveyance of coal along the roadways, which was produced in immense volumes. If it were possible to apply this arrangement to the roads, it would be a similar appliance, on a large scale, to the vacuum-appliances that take the dust out of household-carpets without removing them from the room in which they are laid down. The appliance is successful on a small scale, but it appears to be an impossible arrangement for use in cleaning a large mine in a similar manner. Mr. Thwaite suggested that a supply of oxygen should be liberated by the force of the explosion; but surely such an arrangement would only increase the devastation originally caused by extending the area of damage, and would be the means of setting fire to all combustible material and burning the workmen in the mine, as well as extending the fire to the surface-buildings. The sugggested remedy appeared to be worse than the original catastrophe.

The PRESIDENT (Sir Lees Knowles, Bart.) moved a vote of thanks to Mr. Thwaite for his interesting paper.

Mr. H. HALL seconded the resolution, which was cordially approved.

Mr. S. F. WALKER read the following paper on "Earth in Collieries," etc.:—

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EARTH IN COLLIERIES, WITH REFERENCE TO THE "SPECIAL RULES FOR THE INSTALLATION AND USE OF ELECTRICITY."

By SYDNEY F. WALKER.

Introduction.

The writer has attached, as an appendix to this paper, so much of the "Special Rules for the Installation and Use of Electricity" as refer directly to connections to "earth."

Three points appear to be evident from these Special Rules:—(1) The object of the Departmental Committee, in all the Special Rules, is to minimize the danger of shock, and of fire, but principally of shock. (2) They wished to keep "earth" completely out of any electric system in use in collieries. And (3) they wished to ensure that, under no circumstances, could anyone about the mine place himself in such a position that a dangerous current could pass through him; or, in other words, that no dangerous pressure should exist between the ground, floor, etc., that men about the mine must stand on, and any object they might touch. The writer proposes to discuss the question as to how far the objects of the Departmental Committee have been or are likely to be accomplished by the working of the Special Rules.

What is Earth?—Perhaps it may be as well to clear the ground a little, by enquiring what is meant by "earth?" The term has come down to us from the very early days of electricity, when it was supposed that "the Earth" was an infinite reservoir of electricity, into which any quantity of current might be passed, and from which any quantity might be called up; that it bore the same relation to the electric currents used, as the mass of the ocean bears to the water used for domestic purposes; and in those days the idea was not very inaccurate. Earth, in those days, performed the useful office of a return-wire for telegraph-currents, and it really did not matter whether

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the Earth acted as a reservoir, or whether the currents actually passed through the Earth's crust; and whether any portion of, say, the return-current from Manchester to London passed by way of Glasgow or not. With the development of electrical engineering, however, the whole problem has changed. Telegraph-engineers discovered, many years back, that the Earth had resistance, and that in some localities the resistance was so high that earth could not be used as a return, in the ordinary way. And gradually the proper knowledge of the matter has been worked out, that the Earth's crust is a conductor, just as other bodies are; or it would be more correct to say that it conducts, when sufficient pressure is applied to points at its surface to overcome its resistance, again just as any other body. Every substance forming the Earth's crust has its own resistance, and will conduct strictly in accordance with the laws of electricity as they apply to other bodies; and this applies as fully to the substances in and about a coal-mine, as to other parts of the Earth's crust.

In all parts of the Earth's crust, there are two substances which are largely engaged mainly in conducting any electric currents that are passing through the Earth's crust, that form a large percentage of the effective path through it, metals that are laid in or on the surface, and water, often impregnated with mineral salts, held in the pores of the strata. But every substance, whether porous or not, and whether it carries moisture or not, has its own resistance, and will conduct strictly in an inverse ratio to that resistance, and directly as the nett pressure available to drive currents through it. Water-pipes, tram-rails and wire-ropes, will play an important part in coal-mines in the conduction of any currents that are delivered to earth, but the strata themselves will also perform their share, strictly in inverse proportion to their resistances.

In this connection, the measurements recently taken by Mr. G. C. Wood,* under the supervision of Prof. H. Stroud at the Armstrong College, Newcastle-upon-Tyne, are of the very highest importance. From a perusal of Mr. Wood's paper it will be seen that coal has a very high resistance, bearing comparison, in fact, with some of the substances employed for insulation; and it follows that any conduction that takes place must be, for

* *Trans. Inst. M. E.*, 1905, vol. xxx., page 99.

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practical purposes, by the tram-rails, water-pipes (where they are present) and wire-ropes, assisted, as far as they can be assisted, by the "thill," this having an enormously lower resistance than the coal.

Protection from Shock.—In the great majority of cases, a man receives a shock in a coal-mine, because his feet, being already in connection with a conductor, his hands, his body or his head make contact with another conductor, between which and the one he is standing on, there exists a sufficient electrical pressure to drive a dangerous current through him. Protection means then, so arranging that he cannot, wherever he may be standing, in or about the mine, come into contact with any conductor at more than a few volts difference of pressure from the ground, floor, or whatever he may be standing on. There are two methods of accomplishing this, both of which are made use of in the Special Rules.

A large portion of the possibly available pressure may be used up by the interposition of a high resistance in the path of the current through the man, and this method is adopted in the Special Rules* quoted for protection at the switchboard where either gloves, mats or insulated floors are to be provided. It can also be accomplished by lowering the available pressure at all points where shocks can be obtained, and this is the method commended by the Departmental Committee in the Special Rules† referring to earthing. In all of them, the idea is, that all metallic surfaces that anyone can possibly touch shall be placed at a very low difference of pressure from the ground, etc., upon which everyone about a mine must stand. All metallic surfaces that it is possible to touch are to be brought to such a condition electrically, that the difference of pressure, between them and the ground on which men about the mine must stand, is reduced to very small figures, say less than 50 volts: this being accomplished by armouring all cables, or enclosing them in pipes; enclosing all switches; and earthing all armour, pipes, frames of machines, cases enclosing switches, etc.

And here comes in the question, what do we mean by connecting to earth in this matter? Broadly speaking, the coal-mines

* Section I., No. 10; and Section II., No. 5.

† Section I., Nos. 1, 2, 3 and 5; Section II., No. 6; Section III., Nos. 1 and 2; and Section VII., No. 2.

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in this country may be divided into two classes, for this purpose, those in which there is water in the workings, with pumps and water-pipes leading from the pumps to the shafts; and those in which there is none. In the former set of collieries, earth means the water-pipes, *plus* the tram-rails, and the strata on which they are laid; and efficient earth means good electrical connection between the water-pipes, and the ground upon which men may be standing when they may grasp a cable, or other conductor; and good electrical connection between armour, etc., and the water-pipes. As there is usually a good deal of water on the roads, when there is water in-bye, the connection between the water-pipes and the floor of the roads is sufficiently good to call the latter "good earth," for all currents of moderate strength; and, therefore, so far as protection is afforded by connecting to earth it is obtained in these collieries with currents of moderate strength. But it is a very doubtful matter, if protection is obtained by connection to earth, in this way, where earth is of the best of its kind.

It is somewhat erroneously supposed that connecting two conductors together puts them at the same pressure, and neutralizes any difference of pressure that exists between them. The same idea prevailed in the early days of electric lighting, when it was proposed to connect two or more generators in parallel. It was gravely stated that the mere connection of the plus poles of two dynamos together, and the minus poles together, rendered the pressures delivered by the two machines the same, without taking any other measures to equalize them; and a large number of apparently mysterious burnt-out armatures was the result. Two or more dynamos can be run together in parallel, provided that the precaution is taken of making the pressures which each delivers at the point of common connection, the omnibus-bars, equal; but the mere connection of the terminals together does not render the pressures equal. What is done in such a case is to provide an additional path for a current, through one or more of the dynamos, due to the difference in the pressure generated by the individual dynamos. It may happen that the machines connected together deliver the same pressure, but more frequently they do not, and each of them takes the whole load, *plus* that offered by the additional path through the other machines, in turn, instead of its being divided between the whole of the machines running.

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The writer has mentioned this case, as one instance of the fallacious ideas that have prevailed from time to time. Paralleling of dynamos i; now carried out by equalising the pressures before connecting them. Similarly, if two cables are armoured, the armour being earthed efficiently, and if the insulation of one of them breaks down, the armour becoming alive, the pressure in the conductor that has broken down is not thereby neutralized: only an important portion of the resistance from one path, the path through the insulation, that is open to the pressure of the service, is removed. And, though nothing may happen immediately, conditions may easily arise in which a dangerous pressure may exist between some metal that a man can touch and the floor upon which he is standing; and that not only despite the presence of the efficiently earthed armour, but in consequence of it, if the insulation of one cable has broken down. So long as the insulation is perfect, all will be well, but immediately one armour becomes alive, a totally different set of conditions is produced, the full scope of which it is difficult to forecast. There would be differences of pressure between the armour on different parts of the cable; and, although these may not be great at first, when things are comparatively new, the constant changes, the constant deteriorations that are going on, may produce the very difference of pressure which it is the object of the Departmental Committee to avoid.

It appears to the writer that if earth is to be admitted into the system, by far the best plan would be to adopt the system of concentric uninsulated return. With that there is no question of obtaining good earth; the return-path is necessarily perfect, or the system cannot work. This system can be applied to three-phase, as well as to continuous, current.

The Special Rule, quoted from Section VI., affords a striking commentary on the whole question. If electric locomotives are established in coal-mines in this country, and earth be permitted on the power-supply system, the currents will find their way from the locomotive system to the power-system and *vice versa*, no matter how carefully the two are separated, if the insulation of either supply-cable breaks down.

It should be remarked also, that leaving out other matters, earthing any part of any system increases the probability of shock to attendants who have to trim brushes, see to fuses, etc.,

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and this particularly applies to earthing the neutral wire of polyphase systems, etc.

Earth: where there is no Water inbye.—In the foregoing paragraphs, the writer has dealt with the most favourable conditions for obtaining earth; but, where there is no water in the workings, and where the mine is dry and dusty, it will be found very difficult to obtain earth at all. Earth, to be efficient, must be of sufficiently low resistance to make very little charge upon any pressure delivered to it, in other words, to allow the passage of currents freely through it. According to the measurements referred to above, by Mr. Wood, the resistance of coal ranges from 33,000 million to 80,000 million ohms as against copper, 0·001,59 ohm; while contact with the coal would be very difficult to obtain, and would add to its resistance. The resistance of the underlying stratum, the thill or floor, is very much less, ranging according to Mr. Wood's measurements from 13,000 to 105,000 ohms. According to the measurement of Mr. W. Moon, of the Postal Telegraph Engineers' Department,* the resistance of some clays is less, ranging from 2,500 to 23,500 ohms, when mixed with sand and gravel.

Apparently, the only possible earth obtainable is by connection to the floor, and the actual earth-path will be by way of the tram-rails *plus* the floor itself. It will be, therefore, interesting to see what the resistance of the possible earth-path is likely to be in these collieries. In cases of this kind, it will be evident that it is the worst case that must be provided for, the case where the resistance is highest. The resistance offered by the earth-path will be made up of two quantities, the resistance of the strata which form the path, that of the tram-rails which assist it, and that of the connections between the tram-rails, and other metal used and the strata. Connections to earth are proverbially difficult to arrange, except in the case where two metal-plates can be immersed in a body of water, common to both ends of the circuit, or to two bodies of water connected by other bodies of water of large volume. The resistance of the connection between the plates used as earth-plates and the earth follows the same law as other resistances: it varies inversely as the sectional area of the strata embraced by the plate, or whatever is making the

* "Earth Connections," *The Electrical Review*, London, 1904, vol. liv., pages 485 and 526.

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connection. But this is varied by the fact that the current itself, in its passage, creates an opposing pressure at the surface of the plate, which, by reducing the available pressure, practically increases the resistance; and this polarization, as electrical engineers call it, is approximately proportional to the strength of the current passing across the junction. The resistance opposed to the passage of the current, at the junction with the strata, will depend also upon the substance that is employed. Metals offer the least resistance, other things being the same, as in all other cases; and wood will offer a high resistance, especially where there is coal-dust between it and the floor.

The resistance of the stratum forming the floor or thill varies directly as the length of the stratum through which the current passes, and inversely as the sectional area. That is to say, the farther inbye that the earth-connection is required, the greater will be the resistance offered to the passage of current through the floor, and the thicker the stratum, the lower will be its resistance. The resistance of a very thin floor will be very high, unless there is a stratum underlying it, with which it is making good electrical connection, and which is of a comparatively low resistance. Faulting of the strata will also play a very important part in this matter, as the effective area of the floor available for the conduction of currents passing in the earth-path, will be bounded by faults, for practical purposes. The stratum against which the floor abuts at a fault may be fairly conductive, but there will always be introduced into the earth-path a considerable additional resistance, owing to the passage of the current from one stratum to the other.

As to the probable resistance of such an earth-path, the writer has worked out the following formula for the resistance of the path formed by the strata alone, which it will probably be safer to assume as the path to be used for calculations:— $R = SL \div WT$: R being the resistance of the stratum between the point that is to be connected to earth, and the nearest point where really good earth can be obtained; S, the specific resistance per cubic inch of the floor, or whatever the stratum may be, that forms the earth-path; L, the distance in yards between the point where good earth may be obtained, and the farthest point where it is wanted; W, the width in yards of the underlying stratum between faults; and T, the thickness of the same in

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inches. By specific resistance per cubic inch is meant the resistance between opposed faces of a cube, 1 inch on the side. The measurements made by Mr. Wood and by Mr. Moon, were per cubic centimetre, as is usual in laboratory-work. The writer has converted the figures to per cubic inch in order to simplify the calculation, since all other measurements are in inches, feet or yards.

Taking the specific resistance per cubic centimetre of the floor as 10,000 ohms; this is probably a low figure (Mr. Wood's lowest is 13,000 ohms), and equals approximately 4,000 ohms per cubic inch; and taking a thickness of floor of 1 foot, and a width between faults of ½ mile, the writer makes the resistance for a length of 1 mile of the stratum, between the inbye-point where good earth is obtainable, 666 ohms; for 2 miles, 1,333 ohms; and for ½ mile, 333 ohms. With a width of 1 mile between faults, the thickness being the same, the writer makes the resistance for 1 mile, 333 ohms; for 2 miles, 666 ohms; and for ½ mile, 166½ ohms. With the last values, if the thickness of the stratum is only 6 inches, the resistance becomes again 666, 1,333 and 333 ohms respectively, and the other values are in proportion. The above results are given, merely to show what the resistances are likely to be. There is the conductive path offered by the tram-rails, but the writer fears that this will not reduce the resistances very much. There is the contact-resistances between each rail and the sleepers upon which it rests, and between the sleepers and the floor, and both of these will be high, while there will be very little assistance from the continuity of the rails. If half the total resistances, as given above, or as deduced from the formula, are taken, as the result of the combined paths of the floor and the rails, probably the calculation will be more favourable than actual experience would warrant.

The matter is one for actual measurement, and the writer understands that further measurements are to be made at the Armstrong College on contact-resistances. Meanwhile, there is sufficient information at hand to say that the probable resistances of earth-paths in dry and dusty mines will be absolutely prohibitive. To be efficient, the total possible resistance of an earth-path that is to be capable of protecting on all possible occasions, should not exceed a small fraction of an ohm. The office of the earth-path, if it is to accomplish the object assigned

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to it by the Departmental Committee, is to neutralize all but very low pressures, under all possible conditions, and this can only be done, if at all, with the large currents that will be used, or that may have to be accommodated in the process, by a path of very low resistance. As mentioned above, if earth is to be admitted into the system, there is only one method of accomplishing what the Departmental Committee desire, that is, by using the plan adopted by Messrs. Mavor & Coulson of an uninsulated return, completely enclosing the live conductor. This plan can be arranged with three-phase by making one of the three conductors the uninsulated return, the equivalent of the arrangement on the railways using three-phase currents, the currents being delivered to the trains from two overhead wires, the rails being the equivalent of the third wire.

In the foregoing section, the writer has had in his mind, principally, the question of protection from shock, but the question of protection from fire is quite as important, and for that "earthing" at its best appears to him to be attended with very great risks, on account of the large currents, often leading to sparking, and to arcing that may have to pass by way of earth.

Apparatus for Recording Leakage.—Several appliances have been placed on the market, since these Special Rules were promulgated, designed to accomplish the object set out in the seventh Special Rule of Section I., all being based on the same general principles. Earth may be taken to be a conductor with which either conductor of a supply-service may, and does, at times, become more or less in connection, and the amount of the connection that either has made will be indicated by the current passing between the other conductor and earth, when the other conductor is also connected with earth through an instrument that will denote the passage of leakage-currents. Normally, the two conductors of a two-wire service, or the three conductors of a three-phase service, are separated electrically by the resistance of the insulating envelopes of the two cables, *plus* any resistance that may be present between the exteriors of the cables. If one cable is directly connected to the common conductor, the earth, half the resistance between the two has been removed; and if either is connected in a smaller degree, speaking in the conductive sense, that portion of the total resistance will have been removed.

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In all the instruments on the market, the resistances of the insulating envelopes of the cables are represented by artificial resistances, equal in value, and both large: one end of each resistance being connected to one of the supply-cables and the two resistances connected together at their ends, and the junction connected to earth, a very low-reading ampère-meter being inserted between the junction and earth. If the insulation-resistance of either cable is lessened, the artificial resistance on that side is more or less bridged, or shunted, and the pressure between the opposite cable and earth is increased, with the result that a current passes through the instrument which measures, in certain units (that can be determined by experiment, and are known to the designer), the leakage or the loss of resistance on the other side. When the insulation of both cables is perfect, the pressure at the junction between the two resistances should be *zero*, the supposed pressure of earth, and therefore no current passes through the instrument. As the insulation-resistance of one cable falls, the pressure between the junction and the opposite cable rises, the current which it causes to pass through the measuring instrument being a measure of the fall of resistance of the faulty cable. If the insulation-resistance of both cables falls equally, the instrument does not register the fact, because the point of junction remains the hypothetical *zero*, but any difference in the fall of insulation of the two is registered. To meet these cases, all the appliances on the market are provided with switches on each leg of the artificial resistance, enabling either of them to be disconnected at will. Breaking the circuit of one resistance leaves the connection between the cable with which it is connected and earth still existing; and the amount, it is claimed, is read off in the deflection of the needle due to the current passing through the coil from the opposite cable.

For three-phase working, each cable has its resistance, the three being connected together at one of their ends, and through an ampère-meter to earth. As before, any fall of insulation-resistance is shown by the deflection of the needle, and the fall on each cable is shown by disconnecting it from its resistance. It only requires a simple addition to either apparatus to provide for giving an alarm when a certain minimum-resistance from earth is reached, by ringing a bell, or lighting a lamp.

The early lamp earth-signals, originally introduced by Mr.

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Thomas Alva Edison, the writer believes, in connection with a town-supply service, are still sometimes used for that purpose, and are on the same lines as the apparatus described above. Two lamps, arranged for the full pressure of the service, were bridged between the two mains, the junction between the lamps being connected to earth. As long as all was right, the lamps burnt very dimly, but as the insulation-resistance of one main fell, the lamp connected to the opposite main grew brighter, and if either main was making dead earth, the other lighted up to its full power. The lamps were coloured red and green, as a guide to the attendant.

Regarding all these appliances, it must be understood that for them to be effective, earth must really and truly be represented by a conductive path of very low resistance. With such a path, as has been calculated above, in dry and dusty mines, the apparatus would only work, if the cable made actual connection with the metal that was used for earth. If earth were made in the sump, or the mass of the engine at the engine-room, or the equivalent at the pit-bottom, and a cable rested bare for several feet on the ground inbye, there would rarely be any indication on either the lamps or the ampère-meter.

APPENDIX I.—Special Rules referring directly to Connections to Earth.

Section I.—General.

Rule 1.—(*c*) All metallic coverings, armouring of cables, other than trailing cables, and the frames and bedplates of generators, transformers, and motors other than portable motors shall, as far as is reasonably practicable, be efficiently earthed where the pressure at the terminals where the electricity is used exceeds the limits of low pressure [250 volts].

Rule 2.—Where a medium-pressure supply is used for power-purposes, or for arc-lamps in series, the wires or conductors forming the connections to the motors, transformers, arc-lamps, or otherwise in connection with the supply, shall be, as far as is reasonably practicable, completely enclosed in strong armouring or metal-casing efficiently connected with earth, ...

Rule 3.—Where a medium-pressure supply is used for incandescent lamps in series the wires or conductors forming connections to the incandescent lamps, or otherwise in connection with the supply, shall be, as far as is reasonably practicable, completely enclosed in strong armouring or metal-casing efficiently connected with earth, ...

Rule 5.— . . . . the wires or conductors other than overhead lines aboveground forming the connections to the motors or transformers or otherwise in connection with the supply shall be completely enclosed in a strong armouring or metal-casing efficiently connected with earth, or . . . .

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SECTION II.—GENERATING-STATIONS AND MACHINE-ROOMS.

Rule 6.—All terminals and live metal on machines over medium pressure aboveground, and over low pressure underground, where practicable shall be protected with insulating covers or with metal-covers connected to earth.

SECTION III.—CABLES.

Rule 1.—All conductors (except as hereinafter provided) shall in every case be maintained completely insulated from earth, but it is permissible to use the concentric system with earthed outer conductor, if proper arrangements are made to reduce the danger from fire or shock to the minimum, but the neutral point of polyphase systems and the middle wire of three-wire continuous-current systems may be earthed at one point.

Rule 2.— . . . . Where lead-covered cable is used the lead shall be earthed, and electrically continuous throughout.

SECTION VII.—ELECTRIC LIGHTING.

Rule 2.—Small wires for lighting-circuits must be either conveyed in pipes or casings, ... If metallic pipes are used they must be electrically continuous and earthed. . . .

APPENDIX II.—ADDITIONAL SPECIAL RULES BEARING UPON THE SUBJECT.

SECTION I.—GENERAL.

Rule 1.—(*a*) All electrical apparatus and conductors shall be . . . . efficiently . . safeguarded, and so installed, worked and maintained as to reduce the danger through accidental shock or fire to the minimum, ...

Rule 6.—The insulation of every complete circuit other than telephone or signal-wires used for the supply of energy, including all machinery, apparatus, and devices forming part of or in connection with such circuit, shall be so maintained that the leakage-current shall so far as is reasonably practicable, not exceed $\frac{1}{1000}$ of the maximum supply-current, and suitable means shall be provided for the immediate localization of leakage.

Rule 7.—In every completely insulated circuit, earth or fault detectors shall be kept connected up in every generating and transforming station, to show immediately any defect in the insulation of the system. The readings of these instruments shall be recorded daily in a book kept at the generating or transforming station or switch-house.

Rule 10.— . . . . Gloves, mats, or shoes of indiarubber or other non-conducting material shall be supplied and used where the live parts of switches or machines working at a pressure exceeding the limits of low pressure, have to be handled for the purpose of adjustment.

SECTION II.—GENERATING-STATIONS AND MACHINE-ROOMS.

Rule 5.— . . . . Insulating floors or mats shall be provided for medium-pressure boards where live metal-work is on the front or back.

SECTION VI.—ELECTRIC LOCOMOTIVES.

Rule 3.—In order to prevent any other part of the system being earthed (except when the concentric system with earthed outer conductor is used) the current supplied for use on the trolley-wires with an uninsulated return shall be generated by a separate machine, and shall not be taken from or be in connection with electric lines otherwise completely insulated from earth.

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Mr. J. F. Lee wrote that the author had dealt with a subject which, in view of the Special Rules recently adopted, was of widespread interest, and any information that he could give which would lead to a true method of recording the amount of leakage-current on a three-phase installation would be an advantage. At present, there appeared to be no reliable means of knowing whether there was slight leakage on a three-phase system. Before the Special Rules came into use, the means adopted for roughly testing leakage in a three-phase installation under his (Mr. Lee's) charge was to place an incandescent lamp on the switch-board, one connection being made to the conductor and the other to the "earth," so that if there was sufficient current passing it would be indicated by the glow of the lamp. When the plant was at work, the distinct glow of the lamp shewed that there was a slight leakage on the system. All joint-boxes and connections were thoroughly overhauled, and the cable tested in lengths along the whole distance, but no leakage could be found. The next important point was to find the cause for the lamp lighting when put in circuit with earth; and, after investigation by experts, it was considered to be due to the capacity of the system. As an experiment, a second lamp was put in circuit together with the first; and there was no apparent change in the intensity of the light of the first lamp and the second lamp showed the same glow as the first lamp. Since the Special Rules came into force, one of the recently introduced earth-detecting instruments had been fixed in the same position as that taken by the lamp. It was calibrated so as to read from 1 up to 50 milliamperes, and was arranged so that it could be connected by a switch on to each phase or conductor separately, or on to all three of the conductor-cores combined. This instrument, when connected to earth and to each phase separately, gave readings of 33, 33 and 33¾ milliamperes respectively; but, when connected to the three phases on one side or what was termed "normal point," there was no deflection of the needle. Whether the indicator was an incandescent lamp, or an instrument by which the current could be measured, it was quite clear that there was a current from each phase to earth. Assuming that the deflection shown on the instrument was due to capacity or partly to leakage-current and partly to capacity-current, could Mr. S. F. Walker explain how the leakage-current

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could be measured, and so enable the Special Rules to be carried out by indicating immediately any defect in the installation of the system, as well as the limit of 0·1 per cent. of the maximum current?

Mr. Kenelm Edgcumbe (London) wrote that, in the case of the sixth Special Rule of Section I., extremely vague ideas appeared to prevail as to what was meant by "leakage-current," and it might be well to point out that the leakage, in this case (which must not exceed 0·1 per cent. of the maximum supply-current) was not that flowing from either main to earth, but that flowing from one main through the earth into the other. Several makers had stated that the indications given by their instruments were the actual leakage-currents, as required by the Special Rules. This was, however, not so, since: (1) The indications depended on the resistance of the instrument; (2) they had no relation to the true leakage-currents, as defined above; and (3) the readings were enormously affected by the state of the insulation of the other main, which was not (at the moment) under test. To obviate this difficulty, Mr. F. C. Raphael had devised a set of instruments for various systems, constructed broadly on the lines mentioned by Mr. S. F. Walker. In the case of the direct-current instrument, which was of the moving-coil pattern, a direct-reading table was supplied, from which not only the insulation of each main separately, but also the leakage-current from main to main, could be read at a glance.

Mr. Walker suggested that a bell or other alarm could be readily added, so as to draw the attention of the attendant to the fact that a leak had occurred. In the case of the direct-current instruments mentioned above, this was done; but with alternating current, owing to the fact that there was always a certain capacity-current flowing to earth, the problem was more difficult, and it was not usually found worth while to add the signalling-device.

In his last paragraph,* Mr. Walker rightly stated that none of these instruments would indicate the fact that a few feet of bare cable were resting on the ground, provided that the latter were dry; the reason being, of course, that there was in this case no leakage, and the instruments were only designed to indicate leakage.

* *Trans. Inst. M. E.*, 1905, vol. xxx., page 414.

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The amount of attention now being given by mining engineers to electrical work was most gratifying to electrical engineers, and the problems presented in connection with the satisfactory enclosure and insulation of live parts in a damp mine were extremely interesting.

Mr. W. Moon (London) asked whether, in the measurements made by Mr. G. C. Wood* at Armstrong College, proper contact had been made with the coal, as he had pointed out in his paper† by buttering two opposite sides with clay and pressing tinfoil on them; and whether the coal was in its natural state, as taken from the mine, that is, saturated with moisture, or whether it had been exposed to the air so long as to become quite dry.

For instance, the measurement of the resistance of Permian sandstone of 8,375,000 ohms per cubic centimetre seemed to have been made on dry stone, rather than on the stone as it existed in the quarry. He (Mr. Moon) saturated all the stones that he had measured and then wiped their surfaces before making any measurements of the specific resistances. He appended some measurements (Table I.) of stone that he had obtained from the Bath Stone Firms, Limited; and he regretted that he had destroyed the figures giving the results of his experiments, else he might have given the members some other measurements that would possibly have been of interest.

TABLE I.—SPECIFIC RESISTANCES OF BATH STONES.

Description of Bath Stone.	Specific Resistances per Cubic Centimetre. Ohms.	Description of Bath Stone.	Specific Resistances per Cubic Centimetre. Ohms.
Caen	2,100	Kempstone	10,500
Portland	5,500	Bradford	25,000
Do.	6,400	Ancaster	26,000
Chalk	7,700	Corngrit ...	28,600
Monkspark	8,100	Corsham	31,500
Doubting	9,000	Farleigh	32,000

With regard to the specific resistance of coal, he (Mr. Moon) suggested that cubes, about 1 decimetre, or 4 inches on the side, should be formed in the coal-mine, as the coal was worked. The pieces should then be immersed in a vessel containing water, carried to the laboratory, wiped dry, and measured as described in his paper.

* *Trans. Inst. M. E.*, 1905, vol xxx., page 99.

† *The Electrical Review*, London, 1904, vol. liv.. page 485.

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The writer had made some experiments on the saturation of different stones by water, soaking them for a certain time and cleaving them, and judging from the appearance of the cleaved surface how far the water had penetrated; and he found, with some of the harder stones, that the rate was as low as a centimetre (0·4 inch) a day.

He (Mr. Moon) thought that the possibility of getting earth could only be determined by practical experiments in coal-mines. But, personally, until at least he was in possession of further data, he should say that it would be a mistake to earth any part of an electrical plant in a coal-mine. Two things should be considered in an electrical plant in a coal-mine:—(1) The risk of shock, and (2) the risk of explosion.

With regard to the former, he thought that the normal voltage of the circuit formed only a slight guide as to the danger. One could sometimes handle with impunity a pressure of 500 volts, when the skin was dry and the voltage steady. But even 100 volts were unsafe, if the skin were damp with perspiration and the current was surging in the wires. It was, in fact, not the normal voltage that constituted the danger, but the surgings in the current that might run 100 volts up to 1,000 volts, when, for instance, a faulty motor was being driven. It was well known that men had been killed with the normal pressure of 100 volts.

For ordinary purposes, concentric cables, sheathed and with the sheathing earthed, would seem to be the safest for use. But in a coal-mine, a short-circuit of a concentric cable might cause an explosion, and he suggested that it would be better to keep the two wires of the circuit as far apart as possible, to rely upon their insulation and not to place any earthed conductors, of any sort, near them. He (Mr. Moon) thought that the danger from sparking or short-circuiting was more to be feared in a coal-mine than the danger from shocking; and he anticipated that Mr. S. F. Walker had reached the same conclusion.

It was certainly useless to employ enclosed armatures and fuses, if arcs or sparks could take place between the conductors, or between one of the conductors and an earthed pipe, which could scarcely be kept airtight throughout its length.

Mr. John Gregory said that if the armouring was sufficiently earthed, it was difficult to see how a man standing on the ground

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could possibly receive a dangerous shock. If they assumed that the earth was so poor a conductor that the potential in the live armour, which was earthed, was still maintained, the earth must fulfil the same purpose as the indiarubber mats or gloves. In any case, whilst there was a copper-wire, or other equivalent, connecting the live armour to the earth, it was not probable that a man's body (of infinitely higher resistance) could transmit a dangerous amount of current. The use of an uninsulated return was not, by any means, accepted as a wise proceeding. If it were used, and a man standing on the ground touched any portion of the insulated main, whether at a switch-box, fuse-box, or motor, he was bound to receive the full pressure; but if both mains were insulated, and the insulation was well maintained, the chances were that he would receive a very slight shock, dependent on the effectiveness of the insulation. Even assuming that a fault did occur in a cable and that the armour was made alive, if this was efficiently earthed, it fulfilled the conditions of an uninsulated return. Could Mr. Walker give any particulars of an earth-detecting device which would measure the leakage-current as well as the capacity-current, and discriminate between the two?

Mr. W. C. Mountain (Newcastle-upon-Tyne) said that he had always maintained that, as far as possible in mining installations, it was desirable to use an entirely insulated system throughout. The concentric system, consisting of a copper central core and an iron-wire return (the iron wire being used as armouring and earthed), was, in his opinion, a dangerous and an unsatisfactory system to adopt. He knew of several instances where fatal shocks had occurred through the earthing of the outer conductor, and there was also the possibility of electrolytic action being set up. In addition to this, the system was objectionable, on account of the difficulty of repairs; and, generally, the only recommendation that this system had was one of cheapness. From his experience, the bulk of the trouble, with colliery-installations, had arisen through the accidental earthing of the conductors; it put an undesirable strain upon the insulation of the generators, motors, etc., and certainly 99 per cent. of the accidents to armatures and field-coils underground had occurred through a bad earth on the system.

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He (Mr. Mountain) believed that he originally suggested the use of the earth-detector to the Departmental Committee on the Use of Electricity in Mines. He was well aware of the many accidents that had occurred through earth-leakage, and he felt that some ready method of showing, at a glance, whether the system had maintained its insulation-resistance or not was necessary. His intention was that the earth-detector should be used as an indicator only, but his original suggestion had been considerably elaborated. These elaborations were not called for by the sixth Special Rule of section I. To comply with this rule, a testing-set, consisting of an instrument, which would accurately read the insulation-resistance of the circuits, was required; and an ohm-meter, that was, an instrument to read ohms: these instruments being also styled, "meggers," "ohmers," etc. They consist of a small electric generator, contained in a case, with a driving handle; and they show the insulation-resistance on a dial of any circuit very simply and quickly.

The earth-detector, required by the seventh Special Rule, section I., is merely an instrument (such as a low-reading ampere-meter), which is graduated, and shows whether the insulation-resistance has fallen or not. In the ordinary way, the finger of the instrument would stand at a certain point; if the insulation-resistance fell, the position of this finger would alter, and it would immediately act as an indication that there was something wrong with the system which required investigation, and then the testing set would be required to ascertain what was the actual resistance.

It seemed to him that periodical insulation-tests over the whole of the system were necessary; and he was sure that, if this were done, it would reduce the number of breakdowns of electrical plant very considerably, and be a great saving to the colliery-owner.

It was not so difficult to get a good earth as one would gather from Mr. Walker's remarks; and in his experience, with mining work, the great difficulty had been to prevent earths. It was desirable to have one good earth, and this could generally be obtained by putting an earth-plate in the sump, or by attaching the earth-wire to the pump-columns and water-pipes.

If amoured cables were used, the armouring should be continuous throughout, and if the armouring was efficiently con-

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nected to earth in the way described, the results obtained would be satisfactory. There could be no doubt that it was very necessary, in all systems where armoured cables were used, that the armouring should be properly and thoroughly earthed throughout the whole system.

Mr. JOHN MORRIS said that, in dry mines, the use of the tram-rails, when laid in the ordinary way, for earthing electrical apparatus was absolutely dangerous. Rails, laid on wooden sleepers, often had ¼ inch or more of space at the joints, and it would be a poor earth that would require the current to leap an air-gap of ¼ inch to make it; rails laid on iron-sleepers, with fish-plated joints, were but little better, unless special means were taken to make them electrically continuous; and, for making efficient earth, colliery tram-roads should not be used. Again, there might be, in an otherwise dry colliery, certain places where a little water issuing from the roof might be caught in a little sump, and tanked away. This little sump, on first thoughts, might appear to form a good place for earthing any electrical apparatus that might be near it. It was conceivable, under certain circumstances, that the sump, as a means of making efficient earth, would be nothing better than an earthenware tank; and, due to the resistance of the strata from the little sump to the earthed terminal of the earth-detector on the surface, the detector might show a good insulation while the earth-wire from the little sump to the apparatus supposed to be earthed might be at a dangerous potential: the strata simply acting the part of a choking coil. Consequently, in dry mines, they could not depend on having an efficient earth, unless it were made by an electrically-continuous metallic conductor to some pond, well or running water; and considering the various conditions under which electricity was now used in mines, he (Mr. Morris) doubted whether, under all circumstances, they could depend on having a proper earth unless the current was carried through armoured concentric cables, all apparatus being earthed and the earth-detector being connected to the armouring. Then, on making a good connection to earth from some point of the armouring, they would thus form a proper earth for all apparatus.

Mr. P. C. POPE (Manchester) said that he did not believe that there was an earth-detector, in compliance with the Special

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Rules, on a three-phase installation; but he thought that the best practical appliance was to place an electrostatic earth-detector between each main and earth. In addition, a volt-meter, graduated in ohms, should be used for testing, every day, each main, and reading the actual insulation-resistance to earth on each main. Electrostatic earth-detectors should be placed between each main and earth, and from their construction they would never actually put any main to earth. The only instrument that he had seen used for that purpose was practically a volt-meter, graduated in ohms, and put to earth as described by Mr. Walker. It immediately lowered the insulation-resistance of the whole plant; and, although that might be high, from the fact that the instrument was placed between both conductors and earth, the plant might give a shock to any man. The electrostatic earth-detector would always indicate earth-currents, without at the same time putting the whole installation to earth, the weak point of all the instruments now being introduced into mines. No earth-detector had, at present, been designed, however, which was of any use on a three-phase system, where the neutral point was permanently earthed. He (Mr. Pope) did not think that there was any instrument at the present time that would take account of capacity-currents as well as earth-currents.

Mr. JOHN GREGORY said that Mr. Pope pointed out the danger of connecting the volt-meter through to earth, and recommended the use of an electrostatic instrument; but he was informed that an electrostatic instrument could not be used on the voltages in common use in collieries. He had received particulars of an electrostatic earth-detector, available for 2,000 volts and upwards, but he was advised that it was not suitable for pressures of 400 or 500 volts.

Mr. P. C. POPE said that one particular make of earth-detector would work at a pressure of 20 volts.

Mr. W. C. MOUNTAIN remarked that the seventh Special Rule, section I., did not call for such accuracy as the speakers seemed to suppose.

Mr. JOHN GREGORY said that the rule limited the leakage-current to 0·1 per cent.

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Mr. G. G. L. PREECE said that uninsulated concentric cables should not be used in mines. He had known cases where the outer conductor was doing just sufficient damage to cause leakage, and he had actually seen arcing between the inner and outer conductors. Where armoured cables were used he thought that the concentric was the safest, but they must be insulated, as there was more exposure and increased liability to damage. The difficulty of earthing in very dry mines depended upon whether armoured cable should or should not be used; but, taking all things into consideration, the single unarmoured cable was most suitable for use in a dry mine, so long as metal hangings or similar appliances were prohibited. He agreed with Mr. Pope that electrostatic earth-detectors could be used with low voltages.

Mr. ROSLYN HOLIDAY said that they might use what they thought was earthing, but H.M. inspector of mines might say "this appliance is not efficiently earthed," and the members had looked to Mr. Walker's paper to tell them, once for all, what was good earth. He knew of a colliery where armoured cables had been removed, because the moisture in the air caused them constantly to take fire. From his own experience, he must say that cables were much better if they were well insulated, but without armouring. With this great difficulty of earthing, if they could insure that the armouring was perfectly earthed throughout the whole system, it would not matter if the armouring became alive—nobody could get a shock. But he had not learned any means of ensuring that the armouring was perfectly earthed; and therefore with armoured cables there was great risk of the armouring coming into contact with the conductor.

Mr. SYDNEY F. WALKER, replying to the discussion, said that he had tried to drive home in his paper the fact that in certain mines it was practically impossible to earth. He (Mr. Walker) had written against the use of concentric uninsulated returns for the last twenty years, or as long as the subject had been under consideration. He did not advise it now, but he did say, if they must have armouring, and it must be earthed in order to comply with the Special Rules, that the concentric system was the best, because it afforded warning of a break in the armour. Reference had been made to both mains being insulated and the

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armouring alive and earthed, but, if the armouring was at the same potential as the ground, they would not get a shock. But he maintained that, if a cable was insulated and armoured separately, and the armour was earthed, there would be conditions under which a man would get a shock.

Mr. J. Morris had asked about a device to discriminate between leakage-currents and capacity-currents; but he enquired of the members whether it was really wanted. They knew from hard experience that the capacity-current existed, as the current had to be generated; and they had found out by a process of elimination that it was there, but delicate tests with an apparatus, such as would be required to show its existence and to measure it, would be totally out of place in a mine. He agreed with Mr. Mountain that earth should be kept off the system, and that continuous tests should be made with that object. He agreed with Mr. Morris that, in dry mines, the rails and so on were of no use for earthing; as the current had to travel from the rails to the sleeper, from the sleeper to the ground, then to the next sleeper, and so on, and then to whatever was used as earth: the path being one of very high resistance. He also agreed with Mr. Morris that the little water-sump would be similar to the use of an earthenware tank, and a drop of water in a battery-jar would make as good an earth.

He ventured to prophesy that engineers who used electrical apparatus, especially as current and tension increased, would have trouble unless earth was kept out of the system; and he was glad to find that Mr. Holiday had adopted this view.

Mr. S. Mavor (Glasgow) wrote that Mr. Walker referred to himself as having preached for twenty years in favour of the use of insulated cables without armouring. In the early days of electrical engineering, it was the usual practice, doubtless also followed by Mr. Walker, to mount dynamos and motors on timber bases, so as to insulate their frames from earth. The prejudice in favour of this practice had died hard, but it was dead; and it was now recognized that the best method was not only to refrain from insulating, but definitely to earth the machine-frame. A similar prejudice still survived in the objection to earthing the outer conductor of a concentric cable. Opinions as to the undesirability of earthing the outer conductor of the concentric system were freely given, but there was a singular

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paucity of argument. The general statement was reiterated that it was desirable to maintain the complete insulation of the system. It was forgotten that every tramcar-motor worked with one side connected electrically to earth; and it could not be said that their conditions of service were less exacting than those of motors used in mines. If a motor was not sufficiently well insulated to run with one side connected to earth, it was not good enough for mining work.

Many mining engineers did not clearly realize that the fact of a cable carrying current did not render it a live cable, in the sense that shock might be experienced from touching it. One might, therefore, be excused from here laying emphasis on the fact, that the shock experienced depended on the difference of electric pressure between the cable and earth, and not upon the current passing through the cable. If this were understood, it must be obvious that a system of wiring, in which the insulated conductor (the one at a potential different from that of earth) was completely surrounded by an earthed metallic sheathing (stranded wires over the cable, and cast-iron boxes over switches, fuses, etc.), whose continuity was ensured by its use as the return-conductor, could not be a source of danger to the men in the mine. Access to the inner or live conductor could only be gained by opening the covers of the cast-iron boxes containing the switches, fuses, etc., or at the dynamo- or motor-terminals. Now the Coal-mine Regulation Acts prohibit any but "authorized persons" to deal with such appliances; and the authorized persons know and avoid the certain danger of touching the parts within the boxes or the motor-terminals. There was with concentric wiring, with earthed outer wires, a sharp and unmistakable dividing-line between safety and danger for the authorized person, and there was absolute safety for the unauthorized, so far as he was liable to come into contact with cables and switch-boxes. From the latter class, two of the three victims of fatal mishaps during the past twelve months had been drawn.

As Mr. Walker stated in his paper, the only way of ensuring absolute and permanent safety from contact with cables, if armouring were used, was to adopt the concentric system with an uninsulated return. The difficulty in connection with ordinary armoured cables was the permanent maintenance of the electrical continuity of the armouring throughout the whole

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mine, or of the earth-connections made at various points. In Mr. Walker's opinion, and in that of the present writer, the maintenance of the condition on which safety depended was impracticable. If armouring was not to be used, where was the insulating material to be found that would be permanent, when subjected to the atmospheric conditions of a mine, and of sufficient mechanical strength to resist abrasion? Such a material had not yet been found, at all events it was not in general use; and it was proved by the fact that a considerable number of fatal accidents had occurred by contact with cables, from which the insulation had rotted or had been abraded.

In a recently published summary* of the fatal accidents due to electric shock, which had occurred in the past twelve months, three of these were associated with mining work, and the causes were stated as follows:—(1) Grasping a bare rapper or signal-wire made live by leakage from temporary wiring; (2) found dead grasping an electric cable; and (3) fuse, nipped between the lid and the case of a cast-iron fuse-box, which was ineffectively earthed. Not one of these accidents, and they were the only fatal mining accidents on the list, could possibly have occurred if concentric wiring, with an uninsulated outer conductor, had been used.

Mr. W. Thorneycroft (Glasgow) wrote that an experience of about fifteen years' use of the concentric system of wiring, both for lighting and power, might be of interest to members. It was impossible for anyone to get a shock from the cables wherever they might be, and he believed that it was impossible for anyone not engaged in handling the motors or switches to get a shock at all. For those so engaged, the danger-points were very clearly defined, and the number of such points was only one-half of that of a similar installation on the twin-wire system. The strain on the insulation of the armatures was greater with the concentric, than with the twin-wire system. When an armature developed a slight defect, slight shocks might be got from the motor-casings, when these were bolted down on wooden seats; but before the shock became dangerous the fuse melted and cut off the current. As regarded durability, cables that had been in use for ten years underground had been taken out and put to work in another pit, where they were working to this day. A

* *The Electrical Review*, London, 1905, vol. lvii., page 408.

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cable in a wet upcast-shaft had been in use there for twelve years, and it was still working without trouble. A similar cable in the same shaft was taken out after ten years' work, because the power conveyed by it was no longer required. It was more or less corroded, and was not considered good enough to use again; but, if left alone, it would probably have worked for a much longer time.

One of the motors, served by the cable referred to above as still working, was over a mile from the dynamo; and many engineers said that, under these conditions, electrolysis would destroy the armouring in a short time, and that various other troubles would prevent satisfactory work. But the facts did not support their argument. So far as he was aware, there had never been a burst cable, except as the result of an accident, such as hutches, running away down an incline, striking the cable and crushing it. When this occurred, the current at once made a short circuit, and the fuse on the surface gave way. At the point where the accident occurred, there was a bright flash, caused by the arc, for a second or two before the fuse went. This flash would undoubtedly kindle an explosive mixture of gas and air, but it was of too short duration to set on fire any timber in contact with it.

Any intelligent man could learn to make a junction; but badly made junctions were the cause of most cable-failures.

He might add that several collieries under his supervision had adopted the twin-wire system, but he preferred the concentric system because it was, in his opinion, the safest. It was obviously easier to run one cable to a given point than two; it was simpler and easier to manage; and, as regarded the cost of installation, there was not much difference either way.

Where continuous current up to 500 volts was suitable, he was of opinion that for mining work, both above and below, the concentric system of wiring was the best; but, of course, it must be concentric throughout, and should not be mixed with the twin-wire system.

The PRESIDENT (Sir Lees Knowles) proposed a vote of thanks to Mr. Walker for his paper.

Mr. P. C. POPE seconded the resolution, which was carried with acclamation.

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DISCUSSION OF MR. T. Y. GREENER'S PAPER ON "THE FIRING OF BABCOCK AND OTHER BOILERS BY WASTE-HEAT FROM COKE-OVENS."*

Mr. T. Y. Greener (Crook) thought that it was desirable, in commenting upon the general discussion, to preface his remarks with the statement that he had not the least intention, as some of the speakers seemed to think, of comparing the respective merits of Babcock-and-Wilcox and Lancashire boilers for general purposes, or of advocating the use of one in preference to the other. So far as the facts and figures, that he (Mr. Greener) had set forth in his paper, constituted in themselves a comparison of the results obtainable from the two classes of boilers, that comparison was restricted to boilers fired by the waste-heat from coke-ovens under widely different conditions; and, therefore, the results, although they might fairly be regarded as an indication of the comparative efficiency of the two sets of boilers for a particular purpose, could not be accepted as conveying more than that. The primary object of a coke-maker was to manufacture good coke, and therefore it was quite certain that he would not imperil that object for the sake of a few points of increased efficiency in any boiler.

With regard to Mr. A. L. Steavenson's remarks, he (Mr. Greener) proposed to give some figures, on the lines asked for by Mr. M. Deacon, as to the capital-expenditure involved in installing different classes of boilers on ovens, and those figures would answer Mr. Steavenson's question. He (Mr. Greener) had no reason to think, from his experience of Lancashire and Babcock-and-Wilcox boilers, that the latter were more costly to uphold than the former. In some cases pit-water was used, and in others surface-water; and he confidently expected that at the end of 20 years both descriptions of boilers would be in good working order.

He (Mr. Greener) did not, of his own knowledge, know the calorific value of the coke-oven gas produced from Pease's West coal, but he believed that the value of gas from which the bye-products had been extracted was about 400 British thermal units.

It might be true, as Mr. Gerald H. J. Hooghwinkel stated, that the chimneys attached to the boilers were too low, although he did not think so; if they were higher, the draught on the

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 362.

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ovens would be too great, and there would consequently be waste in burning the coke, and difficulty in regulating the admission of air to the ovens.

The use of spare gas in gas-engines for colliery-purposes would, he (Mr. Greener) had no doubt, be extensively adopted in the future; but, at present, in this country at least, the application of such engines at collieries was only in the experimental stage, and he did not know of more than one colliery at which they had been adopted.

TABLE I.—CAPITAL-OUTLAYS ON BOILERS PER 1,000 GALLONS OF WATER EVAPORATED PER HOUR.

Name of Colliery.	Class of Boiler.	Capital-outlay per 1,000 Gallons of Water Evaporated per Hour.
Ushaw Moor ...	Lancashire, 30 feet long and 7½ feet in diameter	£1,250
Do. ...	Lancashire, 30 feet long and 7½ feet in diameter	1,220
Bankfoot	Lancashire, 30 feet long and 7½ feet in diameter	1,550
Esh	Lancashire, 30 feet long and 8 feet in diameter	1,781
Esh	Lancashire, 30 feet long and 9 feet in diameter*	1,064
Bowden Close ...	Babcock-and-Wilcox, 1,426 square feet of heating-surface	1,758
Bankfoot	Babcock-and-Wilcox, 1,827 square feet of heating-surface	1,427
Stanley	Babcock-and-Wilcox, 2,823 square feet of heating-surface	1,023
Ushaw Moor ...	Babcock-and-Wilcox, 2,823 square feet of heating-surface	862

* Five flues.

The results that Mr. W. C. Blackett had obtained from the Babcock-and-Wilcox boilers at Kimblesworth colliery were remarkably good, and he did not know of anything to equal them elsewhere. It was clear, having regard to the temperature of the flue-gases at the back of the Lancashire boilers at Kimblesworth and Sacriston collieries, that all the heat was not being utilized, and that an additional boiler or an economizer might with advantage be applied in each case.

He (Mr. Greener) did not agree that his calculations should have been based upon an evaporation of 12 pounds of water per pound of coal from a hand-fired Babcock-and-Wilcox boiler. He had not ascertained how much water such boilers would evaporate if hand-fired with Pease's West coal, but he thought

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that it would not exceed 8 pounds, possibly 10 to 12 pounds per pound of combustible in the coal used. Still, having regard to the fact that the coal contained a large percentage of dirt, he was of opinion that the figure used in his paper was about correct.

With regard to Mr. M. Deacon's request for information, as to the comparative capital-outlay on each kind of boiler per 1,000 gallons of water evaporated per hour, he (Mr. Greener) had ascertained the costs of each of the boilers on that basis at the several pits referred to in his paper and the results were recorded in Table I. He (Mr. Greener) was afraid that this information was not of much value for comparative purposes, inasmuch as the conditions in each case were widely different, and, hence, the expenditure in installing the boilers varied in proportion to the relative value of such conditions. He thought, however, that given precisely the same conditions, the cost would not be very different for each class of boiler.

He (Mr. Greener) agreed with Prof. L. T. O'Shea that the results obtained at Ushaw Moor colliery, and by Mr. W. C. Blackett at Kimblesworth colliery, could not be realized with gases from which the bye-products had been extracted; and, with a view of testing the results obtainable with such gases, he had recently had tests made of the evaporation from a Lancashire and a five-flue boiler, fired by waste-heat and spare gas from which the bye-products had been extracted, from 25 Otto-Hilgenstock retort-ovens at Saint Helens colliery. The results were set forth in Table II. The temperature of the gases at the back

TABLE II.—EVAPORATION-TEST OF BOILERS AT SAINT HELENS COLLIERY.

Duration of test	24 hours.
Water evaporated per hour	10,372 pounds.
Coal coked per hour	12,320 ,,
Water evaporated per hour per pound of coal coked	0·840 ,,
Water evaporated per hour at and from 212° Fahr.	0·907 ,,
Temperature of feed-water	162° Fahr.
Pressure of steam per square inch	60 pounds
Temperature of gases at front of boiler	2003° Fahr.
Temperature of gases at back of boiler	800° Fahr.

of the boiler was evidence that the whole of the heat was not being utilized; and arrangements had therefore been made for firing a third boiler with the waste-heat from the Otto-Hilgenstock ovens. These ovens only commenced work about two months ago, hence it was possible that they might not yet have

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attained their full heat. It was estimated, before the ovens were built, that about 1 pound of water per pound of coal coked would be evaporated by the waste-heat; and ultimately that expectation might be realized. He was, however, somewhat doubtful whether it would.

No tests had been made, such as those suggested by Mr. C. C. Leach, to ascertain to what extent, if any, priming took place from Babcock-and-Wilcox boilers. Having regard, however, to the steam-supply from these boilers at each of the collieries mentioned, it was quite certain that the water lost by priming was very small.

Mr. S. F. Walker's remarks were exceedingly interesting and suggestive, and it had not occurred to him (Mr. Greener) before reading them, that it was possible that the steam obtained by waste-heat at the several collieries referred to, could equal in work done that obtainable from gas-engines. He had, however, looked into the figures, and assuming that 10,000 cubic feet of gas were given off by each ton of coal coked; that the gas had a calorific value of 365 British thermal units, and that one-third of it was available for use in gas-engines; and that such engines would require 30 cubic feet of gas per brake-horsepower: then the horsepower from such gas-engines, combined with the horsepower obtainable from the waste-heat, would be just about equal to that capable of being produced from the steam raised from the waste-heat and spare gas in engines using 16 pounds of steam per brake-horsepower. Such engines were not in everyday use at collieries: as a rule, in his opinion, colliery-engines did not consume less than 40 pounds of steam per brake-horsepower, and on that basis the use of gas-engines would be more economical than the use of steam-engines.

Mr. William Severs (Beamish, County Durham) wrote that he had had tests made with the boilers at the Mary pit, Beamish colliery. There are 120 beehive coke-ovens attached to 4 five-flued boilers, 30 feet long and 8½ feet in diameter, with 1,398·71 square feet of heating surface. The feed-water is put into an old cylindrical boiler, placed upon the flue between the boilers and the chimney; and, afterwards, the feed-water is pumped from this boiler to the five-flued boilers placed at the end of the coke-ovens. The average results of several tests are recorded in Table III.

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TABLE III.—RESULTS OF EVAPORATION-TESTS WITH FIVE-FLUED BOILERS HEATED WITH WASTE-GASES, AT BEAMISH COLLIERY, MARY PIT.

	I.	II.	III.	Averages of the three Trials.
Date of trial 1905	Aug. 28	Aug. 30	Sept. 1	...
Duration of tests ... .. hours	6	6	6	...
Temperature of gases at the front of the boilers ... degs. Fahr.	1,750	1,783	1,783	1,772
Temperature of gases at the back of the boilers ... degs. Fahr.	575	616	628	606
Temperature of gases at the chimney ... ... degs. Fahr.	483	531	543	519
Water-gauge at the front of the boilers ... . inches	0·5	0·5	0·5	0·5
Water-gauge at the back of the boilers ... ... inches	0·8	0·8	0·8	0·8
Water-gauge at the chimney inches	1·1	1·1	1·1	1·1
Temperature of feed-water degs. Fahr.	104	104	104	104
Coal coked per hour pounds	16,240	16,240	16,240	16,240
Water evaporated per hour ,,	20,330	23,963	25,373	23,222
Water evaporated per pound of coal coked ... pounds	1·250	1·470	1·560	1·426
Water evaporated per square foot of heating-surface of boiler pounds	3·633	4·283	4·535	4·150

Dr. F. SCHNIEWIND (New York) wrote that there were but few isolated instances of waste-heat boilers, applied on beehive coke-ovens, and, regarding the results of their operations, practically no data were at hand. The comparison between the economy of the waste-heat recovery of beehive coke-ovens, and the conditions of operation prevailing in the bye-product oven were so far apart, however, and so well understood, that they hardly need be touched upon in this connection.

DISCUSSION OF MR. M. R. KIRBY'S PAPER ON "THE COMPOUND WINDING-ENGINE AT LUMPSEY MINE."*

Mr. M. R. KIRBY, replying to the discussion, wrote that of late years some very fine and costly engines had been built for winding, some being compound and fitted with valve-gears leaving nothing to be desired with regard to steam-distribution.

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 380.

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The performances of these engines, however, so far as he had been able to gather, had been disappointing, the lowest steam-consumptions attained being 55 to 60 pounds per actual horse-power per hour. He, therefore, considered that he was justified in stating that the results obtained at Lumpsey mine were satisfactory. However, Mr. John McLaren might be able to inform the members of lower steam-consumptions. The valve-gear at Lumpsey mine was admittedly bad, the good results being due to the low-pressure throttle-valve which was, he believed, unique at the time when it was adopted. He would also like to state here that he was not responsible for the valve-gear. The steam-consumptions, tabulated in his paper, included all the steam used for winding, by the feed-water, air and circulating pumps, and for raising and lowering men; and it was described in his paper as being used for "other purposes."

He (Mr. Kirby) believed that he thoroughly explained in his paper the disappointing results of the condensing tests; and as a large number of tests were carefully made, and agreed pretty closely, he did not consider that there was any error in his figures. He agreed that tests on other winding-plants would be interesting and useful; and it would be desirable that they should be carried out by a committee of the members of the Institution, so as to ensure uniformity.

He (Mr. Kirby) regretted that he was not in a position to give the data asked for by Mr. S. L. Thacker. The only way of stating the commercial efficiency of a winding-engine was to ascertain the amount of fuel used to raise a given weight to a given height, and this result was most easily and accurately stated (as indicated in his paper) as "coal used per actual horse-power-hour."† It would be seen, on referring to the results of the test of March 25th, 1904, of the Lumpsey winding-engine, that while the steam-consumption was highest the evaporation was best, owing to the high temperature of the feed-water.

He (Mr. Kirby) agreed with Mr. B. Woodworth that better results would have been obtained with a cut-off at 80 to 85 per cent. of the stroke: this, indeed, was part of his original scheme, but unfortunately it was not adopted. The several winding-engines were never reversed, and seldom braked to any extent; and the mechanical efficiencies given in his paper were undoubtedly obtained.

† *Trans. Inst. M.E.*, 1905, vol. xxix., page 382.

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Mr. M. Deacon doubted whether so low a steam-consumption as 35 pounds per actual horsepower per hour could be obtained with a non-condensing cross-compound winding-engine. He (Mr. Kirby) hoped shortly to erect such an engine, and he would communicate the results of tests upon it to the members.

He (Mr. Kirby) agreed with Mr. T. C. Futers that, in many cases, it was easy to try to save too much steam at too great an expense.

Engineers usually aimed at commercial efficiency, and if stone could be wound for a less weight of coal with a compound than with a simple winding-engine, that was quite enough reason for its adoption.

The power delivered at the engine throttle-valve, at Lumpsey mine, cost (including fuel, interest on capital, depreciation, upkeep and labour) about 0·55d. per actual horsepower per hour.

He (Mr. Kirby) did not agree with Mr. P. Kirkup that the use of triple-expansion winding-engines should be limited to deep mines, and he pointed to the use of the cross-compound winding-engine at Lumpsey mine, where only 9¼ revolutions were made per wind, in support of this contention.

The poor results obtained by condensing arose from the fact that the condensing plant, which was working on the winding-engine alone, was designed to condense the steam from all the engines at the mine; and, now that it was performing its full duty, it was much more efficient.

It was quite as easy, when drawing stone, to work the Lumpsey winding-engine condensing as non-condensing; for light loads, such as drawing men and shaft-work, the engine was rather quick, and the exhaust-steam was turned into the atmosphere when such work was being done.

Mr. R. H. Fowler (Leeds) wrote that he noted, from the diagrams which Mr. Kirby had taken from the high-pressure cylinder, that although automatic gear was fitted, it did not come into operation. This, he thought, was not to be wondered at, seeing that the engine only made between nine and ten revolutions to complete the wind, and, therefore, there was not sufficient time for the automatic gear to act. He noticed in the remarks that Mr. John McLaren had written on Mr. Kirby's paper that he compared marine and other engines working under the most favourable conditions, and requiring from 11 to 13 pounds of

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steam per indicated horsepower, with the Lumpsey winding-engine, which required from 38 to 42 pounds per indicated horsepower per hour, and was surprised that such a consumption should be tolerated. It appeared to have escaped Mr. McLaren's notice that a winding-engine worked under the most unfavourable conditions, and that it had to put in motion an immense mass of material as quickly as possible, and bring it to rest again, frequently under one minute of time (in the case of Lumpsey in about 27 seconds). He (Mr. Fowler) thought that such a comparison as Mr. McLaren had made was not at all applicable. Taking into consideration all the circumstances with which Mr. Kirby had to deal, he (Mr. Fowler) considered that he decided on the alteration, to the engines as he found them, that would give the most economical results at the lowest outlay; and the saving of fuel, that had resulted, fully justified the change that he had made.

Mr. B. Woodworth (Longton, Staffordshire) wrote that he still thought that the shaft-load efficiency of the Lumpsey mine winding-engine recorded in Mr. M. R. Kirby's paper could not be correct, as it was as high as would, probably, be guaranteed for a high-class continuous-working pumping-engine; and in his (Mr. Woodworth's) opinion a mechanical efficiency of 60 per cent. was rarely obtained from a winding-engine under normal conditions.

He (Mr. Woodworth) felt convinced that the tests were not carefully made, and it was almost certain that a stroke or a revolution, used under steam to finish the wind, had not been taken into account at all. If so, that would reduce the shaft-load efficiency from 10 to 20 per cent.; and there would be retardation of the high-pressure cylinder, owing to steam being stored in the receiver, between the high-pressure and the low-pressure cylinders. The winding-engine at the Ferreira mine showed a shaft-efficiency of 67·8 per cent.; and the shaft-efficiency of the winding-engine at the Village Deep mine was said to exceed 85 per cent.*

Mr. G. H. Winstanley read the following paper on "Mining Education in the Victoria University of Manchester":—

* *The Engineer*, 1906, vol. ci., page 365.

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MINING EDUCATION IN THE VICTORIA UNIVERSITY OF MANCHESTER.

By GEORGE H. WINSTANLEY.

Introduction.—Throughout Great Britain, during the last quarter of a century, there has been a widespread development of what has been called "industrial education," being the practical application of the arts and sciences to the industries. Everywhere in the United Kingdom, institutions have been founded to meet the demand for higher education, and naturally, in most instances, the character of the instruction provided is largely influenced by the industries of the locality.

Mining Education.—Mining generally, and coal-mining in particular (the most important of British industries, not merely because it is helpful, but absolutely essential to all the others), curiously enough has been among the last to receive the attention which its importance deserves, and to have placed at its disposal similar educational facilities to those enjoyed by other industries. It is true that something has been done, here and there, in the past; and recent years have seen the establishment of several important centres of mining instruction. In Lancashire, an institution (in which it has been the writer's privilege to have charge of the Mining Department for twelve years, and until a year ago) has done good work in mining education for nearly half a century. During the period that he had charge of this department, the average number of students attending the mining classes alone was about 140 annually. The record of those twelve years includes 300 successes in the higher stages of the Board of Education (Science and Art Department) mining examinations, including 52 passes in the honours stage; whilst in the examinations for colliery-manager's certificates, in the two Lancashire centres, more than 180 students were successful in gaining certificates of competency. These figures, constituting a record which, so far as the writer knows, is without parallel,

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are given in order to show that, although the Mining Department in the Manchester University is new, and the writer's duties there have scarcely begun, he personally can at least lay claim to some little experience in mining education, as a result of which he feels justified in advising the scheme of instruction which, after conferring with various mining authorities, the Manchester University has decided to adopt.

One by one, the Universities, situated on the coal-fields or near centres of mining industry, have embraced mining education within their field of operations, and in Lancashire it was felt that there was room for something beyond the provision already made. Indeed, a demand had arisen for more advanced education in mining for which (as the seat of learning in one of the greatest industrial cities of the Empire, and the commercial centre of one of the most important British coal-fields) the Victoria University of Manchester felt called upon to provide.

In the establishment of a system of mining education, a difficulty encountered at the outset is that no two authorities seem to be quite agreed as to the best course to adopt. As a matter of fact, from an educational standpoint, mining is quite unlike any other industry, and it is not possible to formulate a scheme of instruction suitable for the training of a mining student on lines which might prove highly successful, say, for a student in engineering. In the management and working of a modern colliery, one requires to possess an intelligent knowledge of nearly all those sciences which are capable of practical application, including mathematics, chemistry, metallurgy, physics, mechanics, geology and electricity. Not only is a knowledge of these matters essential, but one must be able to apply that knowledge usefully in connection with the numerous and varied operations coming within the scope of the colliery-manager or of the mining engineer. At the same time, one must not lose sight of the fact that mining is an industry and not a playground for experimental science; that collieries are not carried on to give scope for the practice of ideas of questionable utility evolved from brains endowed more liberally with ingenuity than with common-sense; but that they are, or should be, profit-earning concerns, which, whilst finding employment and providing a means of livelihood for 800,000 of the dwellers in Great Britain, produce a reasonable return

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for the capital expended upon their development and equipment. Any system of mining education, which loses sight of this fact, entirely fails in its object and becomes worse than useless. The student must be brought to recognize that the chief object of his studies is the practical attainment of efficiency, economy, and safety in mine-management and working.

The writer's experience has led him to the conclusion that an elaborate and costly equipment is quite unnecessary for mining education. The existing physical, chemical, metallurgical and engineering laboratories provide all that is requisite in the way of laboratory-practice for the mining student in his academical career.

For practical work in mining, the best possible laboratory is the mine; and in no other laboratory can the student so satisfactorily acquire practical knowledge of mines and mining. It is quite impossible to provide adequately in the College or University for his practical training: any attempt to do so by the expenditure of large sums of money on model mines and galleries, intended to represent mine-workings, can only give the student an entirely erroneous impression of the real thing; and when, in later life, he passes from the artificial and unreal (where everything can be "made to order," and coming events anticipated and provided for on scientific lines) to the stern realities and responsibilities of mine-working and management, he is quite unfitted for the work before him. Often, too, the student so trained comes upon the scene (perhaps unconsciously) with a distorted sense of his own abilities, even amounting to a feeling of superiority over those possessing the experience of a life-time, and this will have a most unfortunate influence upon his further progress and development. His practical training will suffer also from a disinclination to ask for information, either from a feeling that such a course would appear, in his case, undignified; or more probably because his untrained eye fails to note details which may be of the greatest importance. He has become familiar with phenomena artificially reproduced, with which it is perhaps not well to become too familiar, in the sense that one kind of familiarity begets indifference if not something worse. On the other hand, he is confronted from time to time with conditions which cannot be reproduced in a model mine, and with which he has no previous acquaintance.

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He is taken unawares by occurrences for which his college-training has not made provision, and which do not appear in the programme for the day.

Practical Training.—If he is to become a successful engineer, the mining student must, at the earliest possible stage in his career, become acquainted with the real thing. He must grow up, so to speak, in the atmosphere and environment of the mine; and while he gains experience and widens his knowledge of practical mining, he should simultaneously engage in the study of those sciences which bear upon the operations with which he is daily becoming more conversant.

From the very commencement of his practical training, however, the student should feel that he has some responsibility. This is a feature of the most vital importance; no matter how simple his early duties may be, he should feel that he is personally responsible for something; and, in this way, he develops greater interest in his work, and derives greater benefit from his practical experience. On the other hand, occasional visits to mines and collieries, and summer holidays spent in a sort of conducted tour, which seem to form a feature in some schemes of mining education, must, in the great majority of cases, prove futile. The student becomes a mere privileged visitor who may "look-but-not-touch," and whilst he may regard with interest, at the time, everything that he sees, little or no impression of a lasting character is made upon his mind, because he has not felt the burden of responsibility, or played any part which he could feel was of real use in connection with the work in hand.

Victoria University of Manchester Scheme of Concurrent Practical Training.—In the scheme which has been adopted in the Victoria University of Manchester, these points have been carefully considered, and it has been recognized that there is no useful substitute possible for the training which the student can only acquire in the mine; and that, in the interests of the mining industry, no attempt should be made to find a substitute. Adequate provision is made for laboratory-practice in connection with physics, chemistry, metallurgy and engineering; but the mine is accepted as the best laboratory for practical work in mining. The Victoria University scheme, therefore, provides

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that the student shall have facilities for acquiring practical experience during his academical career, so that he may usefully combine and blend the scientific with the practical. Of course, the University cannot undertake actually to provide the practical training; but, in order to render such a system of concurrent training practically possible, the interest and assistance of a number of colliery-companies has been secured, and these companies, whose collieries are situated within easy reach of Manchester, are prepared to receive, as articled pupils or apprentices to mining engineering, approved students recommended by the University.

Degree Course.—The course leading to the degree extends over three years; and during the second and third years the student spends certain days each week in the University, and occupies himself at the colliery on the remaining days. The intention is that when the student has completed his preliminary or scientific year in the University, he should enter at once upon practical work, spending two days a week at the colliery. During the third year, he is enabled to spend more time at the colliery, the classes and lectures requiring his attendance at the University only on three days of the week. This arrangement, of course, applies to students who desire to concentrate their attention upon coal-mining. The absence of metalliferous mines in the immediate neighbourhood of Manchester makes it impossible to adopt exactly the same course for the student of metalliferous mining; a similar arrangement has, however, been made with the owners of certain metalliferous mines, where the student will spend three months in each year in practical work.

Diploma Course.—To meet the requirements of the Coal-mines Regulation Act for students preparing for the mine-manager's certificate of competency, a two years' certificate course has been arranged.

Mining Lectures.—The mining lectures, of a thoroughly practical character, embrace operations in coal and metalliferous mines, and deal exhaustively with the mechanical engineering and equipment of collieries and mines. As far as possible,

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operations and appliances, capable of illustration, will be placed before the student with the aid of the optical lantern in a fully lighted room, a plan which affords the greatest possible assistance to the student. Lantern-slide diagrams are especially useful in connection with the details of complicated mechanical appliances, which it would be scarcely possible to place before the student in any other way, and by which the action and construction of various appliances can be clearly explained to the student.

Conclusion.—The thirteen years of experience in mining education, during which the writer has been brought into contact with about one thousand mining students drawn from all classes, have convinced him that the concurrent system of mining training, as embodied in the scheme adopted by the Victoria University of Manchester, is the best. His experience has been that the most successful students were invariably those whose practical training and scientific or technical education had proceeded simultaneously.

The PRESIDENT (Sir Lees Knowles, Bart.) moved a vote of thanks to Mr. Winstanley for his paper.

Mr. M. WALTON BROWN seconded the resolution, which was cordially approved.

Mr. J. T. STOBBS read the following paper on "The Value of Fossil Mollusca in Coal-measure Stratigraphy":—

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THE VALUE OF FOSSIL MOLLUSCA IN COAL-MEASURE STRATIGRAPHY.

By JOHN T. STOBBS.

1. Introduction.

It is wellknown that coal-seams are subject to great changes in their commercial qualities; thickness; amount, distribution and nature of their impurities; character of roof and floor; and these changes render their identification over wide areas a matter of great difficulty, and when referred solely to these physical qualities, the result is merely a guess. A most excellent example of the labour and uncertainty of the correlation of coal-seams without palæontology, is given in *An Account of the Strata of Northumberland and Durham as proved by Borings and Sinkings*, published by the North of England Institute of Mining and Mechanical Engineers.* It is desirable, therefore, to call in the support of fossil-evidence, so far as it may be available, to enable us to fix the relative position of the seams, not only in different parts of the same coal-field, but also in different coal-fields. It is one of the objects of this paper to show the extent to which this evidence is in our possession, and has already been used for this purpose.

One of the most disappointing features of the science of geology is its comparative neglect of the Coal-measures. At the present time, our knowledge of the Ordovician, the Silurian, and the Cretaceous systems is much more detailed and exact than that of the 3,000 feet, more or less, of Coal-measures, although the latter are of more importance to civilization than all the other geological formations combined. In proof of this uncertainty and confusion, the following remarks recently made by Mr. Aubrey Strahan, of H.M. Geological Survey, may be cited, and the reference is of greater interest to us

* "No. 452.—Levels of Chirton Colliery, as taken by Mr. John Barnes, 1755," vol. ii., C-E, pages 50-51.

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to-day, meeting, as we do, practically on the ground in dispute. "The difficulty lay in correlating the measures proved at Bradford with those at Astley, and in determining the relative positions of the Bradford Four-feet seam and the Worsley Four-feet seam. There were more than 3,000 feet of strata in question."* Of what other rock-system would such a statement be true to-day? Obviously, this condition of science is just the reverse of what ought to exist, and it is not easy perhaps to make out how it has arisen. No doubt, the extraordinary persistence of coal-seams in comparison with their associated strata, and the ease with which they can be traced, have contributed most to the neglect of palæontology, as a working-aid in Coal-measure exploration.

2. Coal-measure Mollusca in our Museums.

In some measure, the neglect of the mollusca is due to our public museums. Being desirous of seeing lamellibranchs from various coal-fields the writer, this year, made a round of the museums situated at the following important centres, namely:—Manchester, Newcastle-upon-Tyne, Leeds and Nottingham; in every instance the only impression that could be received would be, that locally, plants and fishes were of the utmost importance, and that the mollusca were of little consequence. Manchester, with its magnificent collection of Coal-measure plants, had scarcely a dozen specimens of lamellibranchs, from measures above the Arley mine of Lancashire, properly labelled as to locality and horizon. Newcastle-upon-Tyne, with its classical Hutton collection of plants and its Atthey collection of fishes and reptilia, is in a similar plight with reference to molluscs from the Northern coal-field, above the horizon of the Brockwell seam. Leeds and Nottingham are, if possible, in a worse condition, with respect to the shells from the coal-fields of Yorkshire and Nottinghamshire. The Geological Survey Museum at Jermyn Street, London, is not materially different: it contains, possibly, a hundred specimens of Coal-measure mollusca from all the British coal-fields. With very few exceptions, however, the horizons and localities are not sufficiently indicated to be of any stratigraphical value.

* *The Quarterly Journal of the Geological Society of London*, 1905, vol. lxi., page 322.

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It is too evident, also, that the great teaching establishments in coal-mining centres have failed to impress upon their students the utility of the mollusca as zonal indices.

3. Coal-measure Mollusca: the two Faunas.

All fossils are not equally serviceable to the practical geologist. For instance, a very rare form, however valuable to biological science, is useless in stratigraphy. This reflection was induced by a perusal of the following list of typical and representative Coal-measure fossils given by Dr. Henry Woodward and Mr. H. B. Woodward in their *Table of British Strata*,* namely:—"*Scorpion, Belinurus, Etoblattina, Euphoberia, Cyclus, Lepidodendron, Sigillaria, Calamites, Anthracomya, Megalichthys, Acanthodes, Rhizodus, Ctenodus, Loxomma, Keraterpeton, Anthrakerpeton* and *Anthracosaurus*," which illustrates the danger of lists where the common and rare forms are not distinguished. To be of use to the mining engineer or field-geologist, the fossils must be fairly abundant and sufficiently well-preserved to ensure determination of species; their range, vertically limited, and horizontally extensive. In that portion of the Coal-measures which is characterized by the occurrence of numerous coal-seams of workable thickness, the mollusca answer these requirements most admirably. To particularize, this sequence comprizes, in Northumberland and Durham, all above the Victoria and Brockwell seams; in Lancashire, from the Arley mine to the Ardwick *Spirorbis*-limestone series; in the Yorkshire and Nottinghamshire coal-field, all above the Silkstone or Blackshale seam; in North Staffordshire, from the Bullhurst seam to the Half-yards ironstone; in South Staffordshire, from the Deep mine to the base of the Red Coal-measure clays; in Glamorgan, from the Engine coal-seam to the base of the Pennant Grit. These measures well deserved a descriptive name, and Sir Andrew Ramsay termed the succession "the true Coal-measures." This sequence has now been subdivided and correlated by means of marine horizons, freshwater-lamellibranch zones and entomostracan limestones; plant- and fish-remains have also been used by Mr. Robert Kidston and Dr. Ramsay Heatley Traquair respectively, but notice of their work does not lie within the scope of this paper.

In the Coal-measures, there are two molluscan faunas, which are never intermixed—a marine type and a freshwater type.

* London, 1901.

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During the last few years, considerable attention has been given to the study of these faunas, the most important features of which are that they are easily distinguishable and they are not commingled. Unfortunately, general statements to the contrary are on record. Recently, Mr. A. Strahan said "Though differing from the open-sea deposits which preceded them, the Coal-measures were almost certainly not fresh-water. The *Anthracomya* is known to have lived side by side with true marine molluscs, and the *Carbonicola*, though allied to a great fresh-water family, is always found in close attendance upon the *Anthracomya*."* Particulars of horizon and locality should have accompanied this statement. If *Anthracomyæ* were found side by side with marine fossils on a colliery spoil-heap that would be sufficient validation. The writings of such workers as Messrs. E. W. Binney, J. W. Kirkby, William Molyneux and George Wild, are opposed to this teaching, and recent experience in collecting from marine horizons is equally emphatic.

I.—*Marine Horizons.*

Strata containing marine fossils occur at frequent intervals throughout the true Coal-measures. They often constitute the roof-measures of a coal-seam, and usually contain a large number of fossils; and although the mollusca predominate, they are occasionally accompanied by echinoderms and fishes. The marine bed is generally a black, dark-grey, or grey laminated shale, indistinguishable in its lithological character from other Coal-measure shales. Calcareous bullions, however, occasionally form a noteworthy feature in these shales, as in the roof of the Upper Mountain mine of Lancashire, the Pennystone of South Staffordshire and Coalbrookdale, the shales below the Twist coal, and the roof of one of the Rider coals of the Seven-feet Banbury of North Staffordshire. These bullions should be carefully split along a plane parallel to their bedding, when they will generally reveal fossils in a beautiful state of preservation: they are especially worthy of the attention of collectors. The marine deposits are never very thick—varying

* *Memoirs of the Geological Survey of England and Wales: The Geology of the South Wales Coal-field. Part II.—The Country around Abergavenny, being an Account of the Region comprised in Sheet 232 of the Map*, by Mr. Aubrey Strahan and Mr. Walcot Gibson; *with notes* by Mr. J. R. Dakyns and Prof. W. W. Watts, 1900, page 84.

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from 12 feet down to about 3 inches. When very thin, they may easily escape notice, unless specially looked for. The writer is of opinion that these horizons offer the best means of correlating the coal-fields of this country, marking definite, dead-level planes of deposit, over large areas. It is earnestly to be hoped that special search will be made for them in all future sinkings and borings in those coal-fields where few, if any, have as yet been recognized. The writer holds the conviction that they will be found, if looked for.

The mollusca are represented by brachiopoda, cephalopoda, gasteropoda and lamellibranchiata, and the most important forms are:—

(*a*) *Brachiopoda:*—(1) *Lingula mytiloides.* This is nearly always present in large numbers, and sometimes is confined to the topmost layer of the band, unmixed with other species, and thus proving the last survivor of the transient marine conditions.

(2) *Orbiculoidea nitida.* Although this is not so common as *Lingula mytiloides*, the two forms are generally associated together.

(3) *Productus scabriculus.* Very abundant in the Chance Pennystone of Coalbrookdale.

(4) *Chonetes laguessiana.*

(*b*) *Cephalopoda:*—(1) *Goniatites.* Retaining, for the moment, this old-fashioned generic name for certain cephalopods which are very abundant in marine bands, and are, of themselves, sufficient to indicate the marine character of the deposit, we occasionally find them so badly-preserved that whilst no specific determination is possible there can be no doubt that they are goniatites. *Dimorphoceras Gilbertsoni* is one of the commonest forms. *Gastrioceras Listeri* is characteristic of the lowest portion of the Coal-measures.

(2) *Orthoceras.* Individuals referable to this genus are frequently met with, although their specific determination is generally impossible.

(3) *Nautiloids.* These are of rarer occurrence.

(*c*) *Gasteropoda:*—Specimens referable to this class are also comparatively rare, and they are therefore not so useful in stratigraphy.

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(*d*) *Lamellibranchiata*:—(1) *Pterinopecten papyruceus*. This shell is one of the most abundant in the marine horizons of the Coal-measures. By reason of its size and shape it readily attracts attention. It is generally associated with goniatites, and together they form, perhaps, the most useful indices of the marine character of the stratum.

While the following forms are not so abundant, they have a wide distribution:—

(2) *Ctenodonta lævirostris*.
(3) *Myalina compressa*.
(4) *Nucula gibbosa*.
(5) *Posidoniella lævis*.
(6) *Pseudamusium fibrillosum*.
(7) *Pterinopecten carbonarius*.
(8) *Solenomya primæva*.

II.—*Marine Bands of Coal-fields.*

It will be understood that any of the species enumerated may be found at any of the marine horizons, for aught that is known to the contrary—and in this respect they differ from the lamellibranch-zones described later. There is a marked difference in the richness of the fauna, not only at different horizons, but from locality to locality in the same horizon.

The writer has drawn up a list, shewing all the marine bands at present recognized in each coal-field, arranged in descending order, that is, the newest at the top.

Northumberland and Durham Coal-field:—(*a*) Ryhope colliery: discovered during sinking at 951 feet from the surface or 592 feet from the base of the Permians at that locality.* This point is 17 feet 4 inches above the Five-Quarter coal-seam.

(*b*) East Rainton: met with in boring, 888 feet below the Hutton seam.†

Lancashire Coal-field:—(*a*) Bradford colliery: Mr. John Gerrard, H.M. inspector of mines, recently discovered a grey

* "On the Occurrence of Marine Fossils in the Coal-measures of Fife," by Mr. J. W. Kirkby, *The Quarterly Journal of the Geological Society of London*, 1888, vol. xliv., page 752.

† "Rock-cores from a Diamond-boring at East Rainton," by Prof. G. A. Lebour, *Proceedings of the University of Durham Philosophical Society*, 1897, vol. i., page 69.

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shale from a depth of 2,076 feet, containing *Lingula mytiloides*. It was a very diminutive form, freely distributed through the shale, and not confined to one layer: the writer is indebted to Mr. Gerrard for courteously shewing him the débris from the sinking.

(*b*) Ashton-under-Lyne: exposed in the banks of the river Tame, about 450 feet above the Great mine.* C.

(*c*) Victoria colliery, Standish: Mr. John Gerrard also discovered this bed, about the horizon of the Arley mine.† B.

(*d*) Dulesgate, Colne, Rochdale, Staleybridge, etc.: roof of Bullion coal or Upper Mountain mine. A.

Yorkshire, Derbyshire and Nottinghamshire Coal-field:—(*a*) Gedling colliery: found by Mr. Walcot Gibson during sinking, 524 feet above the Top Hard seam.‡

(*b*) Gedling colliery: found by Mr. Gibson during sinking, 258 feet above the Top Hard seam.‡

(*c*) Midland Railway: cutting, between Pilsley Junction and Clay Cross; the horizon has not been determined.§

(*d*) Middleton colliery, Yorkshire: 82 feet above the Silkstone coal-seam.‖ B.

(*e*) Vicinities of Leeds, Bradford, Halifax, Penistone and Sheffield: roof of the Hard bed or *Pecten*-seam. A.

North Staffordshire Coal-fields: Potteries:—(*a*) Chell and Foley collieries: roof of the Bay or Lady coal-seam.

(*b*) Priorsfield, Longton: roof of the Priorsfield ironstone.

(*c*) Nettlebank and Speedwell collieries: below the Twist or Gin mine. C.

* Marine shells, discovered by Mr. A. H. Green, *Memoirs of the Geological Survey of Great Britain and of the Museum of Practical Geology: The Geology of the Country around Oldham, including Manchester and its Suburbs (Sheet 88 S.W., and the Corresponding Six-inch Maps 88, 89, 96, 97, 104, 105, 111, 112; Lancashire, 259, 271)*, by Mr. Edward Hull; *with an Appendix on the Fossils*, by Mr. J. W. Salter, 1864, page 64.

† "Presidential Address," by Mr. John Gerrard, H.M. Inspector of Mines, *Trans. Inst. M.E.*, 1904, vol. xxviii., page 363.

‡ *Memoirs of the Geological Survey: Summary of Progress of the Geological Survey of the United Kingdom and Museum of Practical Geology for 1902*, 1903, page 14.

§ *Ibid.*, pages 15 and 16.

‖ "On the Fossil Animal Exuviæ of the Yorkshire Coal-field," by Mr. Henry Denny, *Proceedings of the Geological and Polytechnic Society of the West Riding of Yorkshire*, 1845, vol. ii., page 293.

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(*d*) Florence colliery and Slippery Lane: a short distance below the (*c*) horizon.

(*e*) Longton Hall colliery: about 110 feet above the Moss coal-seam.

(*f*) Silverdale No. 16 pit, Sneyd, Berry Hill and Florence collieries: roof of the Moss Cannel or Single Two-feet coal-seam.

(*g*) Leycett, Minnie pit, Halmerend, Hayes Wood, Talk-o'-th'-Hill, Birchenwood (No. 18), Sneyd and Norton collieries: above the Seven-feet Banbury coal-seam. **B.**

(*h*) Weston Sprink: horizon unknown.

(*i*) Knypersley Reservoir: below the Winpenny coal-seam.

(*j*) Wetley Moor: roof of the Crabtree coal-seam. **A.**

Cheadle:—(*a*) Draycott colliery: 71 feet below the Four-feet coal-seam.

(*b*) Churnet Valley: roof of the Crabtree coal-seam, three marine bands. **A.**

Leicester Coal-field:—(*a*) Leather Mill: horizon not exactly known.*

(*b*) Church Gresley: roof of the Ryder coal-seam.*

(*c*) Nailstone colliery: 453 feet below the Lower Main coal-seam.†

(*d*) Nailstone colliery: 507 feet below the Lower Main coal-seam.†

(*e*) Nailstone colliery: 521 feet below the Lower Main coal-seam.†

(*f*) Nailstone colliery: 663 feet below the Lower Main coal-seam.†

South Staffordshire Coal-field:—(*a*) Hamstead colliery: 195 feet above the Thick coal-seam.

(*b*) Between Rowley Regis and High Haden: White ironstone.‡

(*c*) Oldbury: Pennystone ironstone.‡ **C.**

(*d*) Cannock Chase: below the Cannel coal-seam.§

* *Burton-on-Trent: its History*, by Mr. William Molyneux, 1871, page 154.

† Cores in Leicester Museum.

‡ *Memoirs of the Geological Survey of Great Britain, and of the Museum of Practical Geology: Geology of the South Staffordshire Coal-field, etc.*, by Mr. J. Beete Jukes, second edition, 1859, page 58.

§ *Burton-on-Trent: its History*, by Mr. William Molyneux, 1871, page 154.

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Coalbrookdale Coal-field:—(*a*) Freehold, Donnington: Chance Pennystone.

(*b*) Donnington: above the Blackstone.*

(*c*) Lodgewood pit: Pennystone. C.

Bristol Coal-field:—(*a*) Ashton Vale colliery: over a new coal-seam, 270 feet below Gay's vein coal-seam.†

South Wales Coal-field:—(*a*) Beaufort: mine over Bydyllog coal-seam.‡

(*b*) Clydach, Pontypool and Sirhowy: mine over the Engine coal-seam.§

(*c*) Glan Rhymney, Beaufort, Cwm-Bryn-ddu: Rosser veins.‖

The large letters, A, B and C, at the end of some of the lines, indicate the same marine horizon in each coal-field.

III.—*Freshwater Horizons.*

Freshwater lamellibranchs.—Lamellibranchs are by far the commonest shells in the Coal-measures, and since the death of Mr. J. W. Salter, in 1869, they were comparatively neglected in this country, till Dr. Wheelton Hind, in the last decade, took up their study. It is much to be deplored that the Geological Survey, during those years, allowed Mr. Salter's work to be dropped, for it had a direct economic bearing. Dr. Wheelton Hind first reduced the disorganized facts to order, by drawing up a scheme for "zoning" the Coal-measures by means of the three wellknown genera of freshwater lamellibranchs, namely:—*Carbonicola, Anthracomya* and *Naiadites.*¶ Whilst the stratigraphy has required some correction, our extended knowledge of the distribution of these genera has added proof of the sagacity and acumen with which the main palæontological lines were laid down

* "On the Geology of Coalbrook Dale," by Mr. Joseph Prestwich, Jun., *Transactions of the Geological Society of London*, 1834-1836, second series, vol. v., page 445.

† Discovered by Mr. H. Bolton, 1905.

‡ "On the Fossils of the South Welsh Coal-field," by Mr. J. W. Salter, *Memoirs of the Geological Survey of Great Britain and of the Museum of Practical Geology: The Iron-ores of Great Britain*, 1861, page 229.

§ *Ibid.*, page 228. ‖ *Ibid.*, page 221.

¶ "A Monograph on Carbonicola, Anthracomya and Naiadites," by Dr. Wheelton Hind, *Palæontographical Society*, 1895, vol. xlix., pages 154 to 170.

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by Dr. Hind. Some few of the species are of diagnostic value, that is, they are restricted to one horizon. In other instances an "aggregate" of species is necessary as an index of position. In working-out this faunal sequence, the North Staffordshire coal-field forms the type for reference—chiefly because its wonderful palæontological material has been more diligently collected and carefully studied than that of other coal-fields, and in this work the names of Mr. John Ward and Dr. Hind must be mentioned. The result, then, of the influence and teaching of these pioneers, of much discussion with them, and of collection in many of the coal-fields, is that the following seem to be the most important "zones" in the natural order of succession, from the top of the series (of Coal-measures) downwards.

(*a*) *Anthracomya calcifera.* This form is found generally in North Staffordshire, near the base of the Newcastle-under-Lyme series: it is also sparingly found between the two lowest coal-seams in that series, but is abundant in the basal limestones—its vertical range here is about 60 feet. At the same horizon in Glyn Morlas, a tributary of the Ceriog, in the Denbigh coal-field, the same fossil is found;* and at Slade Lane, near Manchester.

(*b*) *Anthracomya Phillipsi.* This is one of the best zonal molluscan forms: it is usually very abundant, and it has been traced over an immense area. Its position in the various coal-fields is given below:—

South Wales: Mr. Walcot Gibson found it in the roof of No. 1 Rhondda seam, near Blaen-gwrath.

Bristol and Forest of Dean: Dr. Wheelton Hind obtained it from one of the seams at Kingswood pit, Bristol, and Trafalgar pit, Cinderford.

North Staffordshire: It is very abundant in the laminæ of the blackband ironstones, the Top Red mine, the Half-yards or Blackband, the Red mine, the Red Shag and the Bassey mine: it is also common in the Gubbinstone at Silverdale, at Forge pit, Chesterton, and in Hanley. Its range here is about 700 feet vertical.

* *Memoirs of the Geological Survey: Summary of Progress of the Geological Survey of the United Kingdom and Museum of Practical Geology for 1900*, 1901, page 101.

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Lancashire: It is abundant in the Upper Coal-measures containing the *Spirorbis*-limestones, at Ardwick, Slade Lane and Bradford colliery.

Yorkshire and Nottinghamshire: Mr. Walcot Gibson found it at Gedling sinking, 524 feet above the Top Hard coal-seam.* It was also discovered, this year, in the railway cutting near Cadeby (Conisborough) in a 3 inches ironstone, 10 feet below the Permian at that locality.†

It is important to recall the fact that Mr. Robert Kidston, in 1893, recognized these red beds as "most probably, if not certainly, Upper Coal-measures."‡ The discovery of *A. Phillipsi* enables us to speak with certainty on the question.

Northumberland and Durham: Last month, the writer was fortunate enough to discover this fossil in the northern bank of the river Wear, opposite Claxheugh, near Hylton. It occurred abundantly in certain nodules of ironstone, and in this position would be about 1,700 feet above the Hutton Seam. These are known to be the highest beds in the coal-field, and it is important to be able to fix their position with respect to the measures in other coal-fields. Until this discovery, no definite idea could be formed of what sequence of measures had been removed by denudation previous to the deposition of the Permian. We now know that the topmost measures in Durham correspond to the top of the "true Coal-measures" in the Midlands, and in South Wales. The pre-Permian denudation has been a boon to the mining-industry in the north, because the measures immediately above the *A. Phillipsi* horizon in other coal-fields are barren of workable seams.

(*c*) *Carbonicola Vinti.* This small fossil—the last survivor of the genus—is found in North Staffordshire in marls and thin ironstone-bands about 30 feet above the Bassey mine, that is, towards the lower portion of the *Anthracomya-Phillipsi* zone. It likewise occurs in the Hylton section, opposite Claxheugh, in the Durham

* *Memoirs of the Geological Survey: Summary of Progress of the Geological Survey of the United Kingdom and Museum of Practical Geology for 1902*, 1903, page 14.

† "Preliminary Note on Upper Coal-measures in Yorkshire," by Messrs. H. Culpin and G. Grace, *Proceedings of the Yorkshire Geological and Polytechnic Society*, 1905, vol. xv., page 330.

‡ "On the Various Divisions of British Carboniferous Rocks, as determined by their Fossil Flora," by Mr. Robert Kidston, *Proceedings of the Royal Physical Society*, Edinburgh, 1893, vol xii., page 210.

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coal-field, described above, and there also it is associated with *Anthracomya Phillipsi*. It is very abundant in both localities. No better index of the position of a bed in the series of Coal-measures is known than the combination of these two forms.

(*d*) *Anthracomya pulchra*. This curious little lamellibranch is found abundantly in the Burnwood ironstone of the Newchapel area of North Staffordshire, and in South Wales in the mine over the Big coal-seam of Rhymney.

(*e*) *Anthracomya Adamsi*. The very size of this shell is such that it cannot escape observation, and it forms an excellent zone-fossil. In North Staffordshire, it is restricted to the horizon of the New-mine ironstone (of the Newchapel area) or the Little mine (of the Fenton area), which by its aid, are known to be one and the same bed. In South Wales, it has been found in the mine over the Big coal-seam at Rhymney, and in the Black Pins and Soap veins of Ebbw Vale. The writer has seen specimens from the Derbyshire and Nottinghamshire coal-field, but the horizon was unknown.

The close association of these two species of *Anthracomya* in districts so far apart as South Wales and North Staffordshire forms a good zonal index.

(*f*) *Carbonicola turgida, Carbonicola subrotunda and Carbonicola gibbosa*. This horizon is fixed by this "suite" of species of *Carbonicola*. In North Staffordshire, it lies about 100 feet above the Moss coal-seam, and has been traced from Burslem to Longton. In Lancashire, *Carbonicola turgida* and *Carbonicola subrotunda* are formed together above the Cannel coal-seam at Hulton colliery. The writer has seen the full "suite" from an unknown horizon in the Nottinghamshire coal-field.

A little caution is necessary in dealing with *C. turgida*, if found singly, as its zone is rather a thick one, extending in North Staffordshire from the Ironstone coal-seam to the horizon given above.

(*g*) *Carbonicola subconstricta* (special variety) *and Carbonicola turgida* (small variety). In the North Staffordshire coal-field, these special varieties are abundant and associated together in

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the roof of the Five-feet coal-seam, which is largely worked on the west side of the coal-field. In this district, they form together a reliable index-band, and it will be interesting to learn whether it holds in other coal-fields.

(*h*) *Naiadites carinata, N. modiolaris, N. quadrata, Anthracomya modiolaris and A. Williamsoni.* In North Staffordshire, this "aggregate-" zone is restricted to the roof of the Hard mine (the Bowling Alley coal-seam of Biddulph). It has been traced throughout the coal-field. In South Wales, the Ras Las coal or Nine-feet coal-seam is at the same horizon—the full "suite" having been found there in the neighbourhood of Rhymney and Dowlais. The writer has also seen all the forms from one horizon in the Nottinghamshire coal-field, but no account could be obtained of its position with respect to a known coal-seam.

(*i*) *Carbonicola acuta*, var. *rhomboidalis.* In North Staffordshire, this variety is restricted to the roof of the Cockshead seam. Associated with it and also restricted to this horizon is a peculiar form of *C. acuta*, where the posterior end is curiously beaked. This may only be an abnormal development of this part of the shell of *C. rhomboidalis*, which in some individuals shows a tendency in this direction.

(*j*) *Carbonicola robusta.* "Mussel-bands," almost entirely made up of this shell, have been found in many coal-fields.

Durham: roof of the Brockwell seam, Horsley Wood, Wylam.

Lancashire: 12 feet below the Arley mine, Chisnall Hall colliery; 54 feet below the Three-Quarter seam, Tyldesley colliery; and roof of the Arley mine, Burnley coal-field.

Nottinghamshire: ironstone-band above the Black Shale coal-seam, Mapperley colliery.*

North Staffordshire: roof of the Cockshead coal-seam; cannel-coal below the Cockshead coal-seam.

South Staffordshire: 30 feet below the Deep coal-seam, Cannock and Rugeley, Wood pit.

South Wales: about the horizon of the Cnapiog coal-seam, Hirwaun.

* *Memoirs of the Geological Survey: Summary of Progress of the Geological Survey of the United Kingdom and Museum of Practical Geology for 1902*, 1903, page 13.

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Caution is also necessary with this shell: its maximum development is at the horizons named, but individuals are found, generally associated with *Carbonicola acuta*, from the Ten-feet coal-seam to the Wetley Four-feet coal-seam of North Staffordshire; and from the Arley measures to the Lower Mountain mine of Lancashire. It certainly characterizes the lowest portion of the "true Coal-measures."

Two of the commonest forms of lamellibranchs, namely:—*Carbonicola acuta* and *Carbonicola aquilina*, are of no use for zonal purposes. The former ranges from the top of the Millstone Grit, right through the Coal-measures, to the horizon of the Radstock series of the Somerset coal-field, where Mr. James McMurtrie found the single specimen now preserved in the South Kensington Natural History Museum. The latter is generally associated with *Carbonicola acuta*, though it has not so great a vertical range.

These freshwater mollusca are generally found in black or dark-grey shales of the Coal-measures. They are frequently in such numbers, and so compressed and cemented together, as to form hard beds termed "mussel-bands:" in this condition the shells are often difficult to determine. Occasionally, however, they occur more sparingly and lie scattered through the shale; in these circumstances they are better preserved and are more desirable as specimens. Sometimes, only casts of their interiors are preserved, and these require much care in naming. Generally, the valves are found with their longer axes parallel to the bedding-plane of the shale: a few instances have been observed of the shell being erect in the shale, as if they had been overwhelmed whilst in the act of burrowing in the mud. In the same band, entomostraca are often found side by side with the lamellibranchs and, not infrequently, the shells have *Spirorbis* attached to them. In collecting, note should be made of these circumstances.

It is probable that they were of freshwater habitat, because of the relationship of *Carbonicola* to the recent *Unio*; some of the *Carbonicolæ* have their umbones eroded, the pitting in many instances being very deep and following the lines of growth of the shell. This erosion is characteristic of freshwater-shells. The complete separation of the two faunas observed *in situ* lends

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strong support to the view, that as one of them is incontestably marine, the other is freshwater.

The development of the genera is also of great interest. Near the base of the "true Coal-measures," when conditions were favourable, we find the large forms, and all three genera strongly represented. *Anthracomya* attains its maximum at the *Adamsi*-zone, dwindling gradually upwards to the *Phillipsi*-zone, and becoming extinct with the diminutive "*calcifera*." Similarly, one of the latest forms of *Carbonicola* is the little species termed *vinti*.

Some of the above zones may possess a local importance merely, but others again have been shown to have a wide distribution. As our knowledge of their distribution grows, some species not mentioned in this paper may prove to be of greater utility, but in all cases experience will teach us within what vertical and horizontal limits they are most helpful. At this stage it would be unwise to claim too much for these zones; so much depends on the stratigrapher. As a matter of fact, however, in North Staffordshire they have been tested and applied in boring, sinking, and proving faults with great economic advantage, and scientific principles that pass the ordeal of commercial application, can no longer be regarded as belonging to the domain of hypothesis.

4. The Mollusca Compared with Plants and Fishes as Zonal Indices.

The writer holds no brief for the mollusca on this question: on the contrary, he rejoices in receiving help from every source. All these organic remains, when scientifically collected and authoritatively examined, should tell the same story as to the age and relative position of the rocks in which they are found. In the Coal-measures, above the *Anthracomya-calcifera* zone, the plants practically have the field to themselves, with the exception of a few entomostracan limestones, which form excellent index-beds. From the top of the *Phillipsi*-zone to the Millstone Grit, the marine bands and the zonal lamellibranchs afford the means of more minute and unequivocal subdivision than the other organic remains. For supplementary work in tracing a single horizon, entomostracan- or *Spirorbis*-limestones, or fish-remains, when these are so abundant in a stratum that it merits the name of

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a "fish-bed," are most excellent. Compared with plants, however, the shells are more abundant in definite beds, their tests were of better material for preservation, and during the period of deposition of the Coal-measures they seem to have undergone more rapid mutation.

5. Conclusion.

For the purpose of the development of this work, local helpers are needed in every coal-field. Every addition to our knowledge of the Coal-measures implies a commercial gain to the coal-mining industry.

The writer especially appeals for help in those coal-fields where little collecting-work has been done hitherto.

Mr. John Morris objected to the statement that *Anthracomya Phillipsi* occurred at "the top of the 'true Coal-measures' . . . in South Wales." The No. 1 Rhondda seam, in which that mollusc had been found, was not at the top of the Coal-measures; there were several hundred feet of strata above the Rhondda seam, and, in that distance, there were at least five workable seams of coal.

Mr. John Gerrard (H.M. Inspector of Mines) said that at Bradford colliery, Lancashire, *Anthracomya Phillipsi* occurred with three workable seams above it; and yet it was perfectly correct to say that it was found in the Upper Coal-measures.

He did not quite agree with Mr. Stobbs in regard to the little aid which geology had rendered to mining or to the mining engineer. Geology had not done as much as it ought to have done, and as much as they hoped it would do in the future; but there were many cases on record, in the Lancashire coal-field, where the knowledge of the fossils found in the seams had proved of great value. At Rishton colliery, Mr. William Pickup, who was in charge of the exploration seeking the Lower Mountain mine, noticed clearly defined shell-beds; and by the aid of these shells, contrary to the expressed views of the workers and those who were said to have known the locality, he directed operations and found the coal-seam. Within the last three or four years, at another colliery, the seam was lost in consequence of meeting a fault, which had an unexpected throw, and the presence of a band, containing goniatites, found

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above a seam, led to the proving of their position and the right direction of search. Over and over again, the discovery of *Carbonicola robusta* had led to the successful termination of search for the Arley mine.

He agreed with Mr. Stobbs that the attention of mining students should be directed to the value of practical geology, it gave them an interest in their work and it would ultimately develop into knowledge of considerable value.

It were more fitting that mining engineers should look up this question: the famous Atthey collection of fishes in the Newcastle-upon-Tyne Museum was made by a grocer; the splendid collection of fossils presented to Owens' College Museum by Lord Shuttleworth was obtained by a butcher; to-day a weaver in Colne was collecting most interesting fossils from the east Lancashire coal-seams; and Dr. Wheelton Hind, although a busily employed surgeon, found time to thoroughly work out the mollusca of the Coal-measures all over the country.

Mr. G. E. J. McMURTRIE said that the Somersetshire coal-field was much faulted, and it was frequently necessary to search for the seams, with very little to guide them except the nature of the ground; but, so far as he knew, in none of the Somersetshire series had any shells been found. An attempt had been made to trace the horizons of the different seams by plant-remains: they had, perhaps, the richest flora in Britain, but it had been, hitherto, of no practical help. He hoped that Mr. Stobbs would succeed in finding in Somersetshire fossil shells of the species described, and thereby confer a great boon on all interested.

Mr. JOSEPH DICKINSON said that the Lower Series of the Lancashire Coal-measures contained a remarkable goniatite, which was associated with the Upper Foot coal-seam above the Gannister seam. He asked whether the same fossil had been found in the Lower Coal-measures of Durham or Northumberland, because it would help to correlate that particular seam with the Lower Series of Lancashire. He believed that the whole of the Coal-measures of Durham and Northumberland constituted the Lower Series of Lancashire.

Mr. SYDNEY BATES (Mickley) wrote that Mr. Stobbs was to be congratulated upon commencing the study, in a practical way,

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of the palæontology of the Coal-measures throughout Great Britain. Hundreds of sections of strata had been tabulated; but, with the exception of a few put down with the diamond-drill, they afforded a very meagre idea of the strata, without considering the flora and fauna of the measures passed through. However, Mr. Stobbs had introduced in a practical form, for the guidance of those who wished to collect from their mines, fossils which would assist in the correlation of the coal-seams.

Mr. Stobbs stated that most of the fossils were of general occurrence throughout the Coal-measures. He (Mr. Bates) had collected fossils from the various coal-seams in the Wylam district; and he had found, with one or two exceptions, that the fauna and flora had horizons practically of their own. Commencing from the Brockwell and lowest seam, there was a bed of shale, varying in thickness from 6 to 15 inches, containing a great number of *Anthracosia*, distributed throughout the shale; and other fossils were of rare occurrence in the strata immediately overlying the seam. The Yard seam, about 60 feet above the Brockwell seam, was immediately overlain by a very coarse clay mixed with nodules of ironstone; then came 7 inches of shale, with layers of *Anthracosia*, but, as stated previously, no other fossils had been found. At the Six-Quarter seam, a little higher up, a distinct change took place: the fauna was absent, *Anthracosia* not having been found in the strata immediately underneath or above this seam; but, in the plant-impressions, *Sphenopteris* and *Pecopteris* were very common, with a number of *Calamites*. The Five-Quarter seam, 27 feet above the Six-Quarter seam, occurred with the above-mentioned flora, with the addition of *Asterophyllites*, which had not yet been found near the Six-Quarter seam. There was nothing of further interest, until the Towneley seam was reached, and there the fauna became very prominent; *Anthracosia* or *Lingula* had not been found, but *Rhizodus* and *Ctenacanthus* had been discovered in the shale adjoining the coal.

Mr. Walcot Gibson (H.M. Geological Survey) fully agreed with Mr. Stobbs as to the value of palæontology in determining horizons among the Coal-measures; and he heartily welcomed the enthusiasm that the author was throwing into the investigation of the marine bands. He (Mr. Gibson) would never forget the experience that he had gained in the North Stafford-

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shire coal-field; and, year by year, additional marine beds were being found in the Derby-Nottingham coal-field, largely as the result of the knowledge gained in North Staffordshire. The marine beds, east of the Pennine chain, were likely to prove of practical importance; but the time had not yet come to draw a comparison with North Staffordshire, except, perhaps, between the marine horizon associated with the Crabtree and Alton coal-seams. Great caution was needed in the correlation of individual seams over wide areas; the imperfection of the geological record, and the really small amount of material yet examined, must be kept in mind. The rapidity with which the Coal-measures were deposited was also an important factor, as it did not allow of those faunal changes, which in a large measure accounted for the greater reliance to be placed on the zones of many of the other formations. It was even open to doubt how far palæontologists would agree even as to the existence of any true zones in the Coal-measures. The term true Coal-measures was an unfortunate one, as every geological formation was a true one. In the Midland districts, the old-fashioned terms of Upper, Middle and Lower, if not strictly of palæontological value, satisfied the stratigraphist and the practical man.

It was gratifying to find that the author acknowledged the claims for each and all of the fossils, whether plants or animals. In the Upper Coal-measures, plants constituted almost the sole evidence; and instances could be quoted where they formed the only data as to the age of the Middle and Lower Coal-measures.

In Mr. Stobbs' correlation of the marine horizons, it appeared to be premature to assert that those associated with the Arley mine and the Seven-feet Banbury coal-seam were the same. What was the name of the fossil that distinguished it from the A or C horizons? Very little was yet known of that above the Arley mine. Was enough known about the C horizon? The A horizon was well established many years ago by Messrs. E. W. Binney, A. H. Green and E. Hull, and was being found over wide areas in Derbyshire by Mr. C. B. Wedd. It was pardonable to make North Staffordshire a type, but it must not be made too much of a type.

At the present time, it was hardly true that geologists were neglecting the Coal-measures. The science of geology, the author must bear in mind, offered a wide field in which the reapers were unfortunately few. If, however, a census of working geologists were taken, it would be found that a goodly

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number (amateur and professional alike) were engaged in the study of the Coal-measures.

Dr. WHEELTON HIND (Stoke-upon-Trent) wrote that he noted with great pleasure and satisfaction that the subject of the identification of definite horizons in the Coal-measures by the various species of mollusca, was being brought prominently before The Institution of Mining Engineers by so strong an advocate as Mr. Stobbs. It was pleasing to find that the horizons of the North Staffordshire coal-field, which he (Dr. Hind) had mapped out some ten years ago, by the various species of *Carbonicola*, *Anthracomya* and *Naiadites*, had proved of value and of economic importance to the mining engineer, and that these horizons held true for other coal-fields. He noticed that the officers of the Geological Survey had recognized that the same broad palæontological lines as those which he had established in North Staffordshire also obtained in the Nottinghamshire and Derbyshire coal-field.* It was stated that three important fossils had not been found in that area; but in the meantime two of them had been found.† *Anthracomya Adamsii* was found at Tibshelf on the waste-heap by Mr. Thomas Norcliffe, and the same fossil was recognized by Mr. J. T. Stobbs in a collection from Gedling, in which he also identified *Anthracomya Williamsoni* from the latter locality. There could be no doubt that, in the past, fossils had been almost entirely neglected by mining engineers and by the Geological Survey; and this was a matter of surprise to him (Dr. Hind), seeing that the mining engineer had received a first-class technical education, and had been taught to observe. He was convinced that if the Geological Survey had employed their palæontologists in the field, instead of confining their energies almost entirely to museum-work, the value of fossil evidence would have been established long ago, and fewer stratigraphical mistakes would have been recorded by the Geological Survey. He hoped that Mr. Stobbs' paper would open the eyes of the mining engineer to the importance of the study of the fossil mollusca of the Coal-measures.

The PRESIDENT (Sir Lees Knowles, Bart.) thought that Mr. Stobbs had found a key to the correlation of the coal-seams. With

* *Memoirs of the Geological Survey: Summary of Progress of the Geological Survey of the United Kingdom and Museum of Practical Geology for 1904*, 1905, pages 5 and 12.

† *Ibid.*, page 12.

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regard to the observation that geology had done nothing for mining, two cases occurred to him in which it might have been, or it had been, of considerable help:—(1) In Caernarvonshire, a mine was pointed out to him, where a sinking had been made below the Carboniferous series; a geologist would have known that the sinking was being made below the Coal-measures. And (2) in Kent, the advice of a geologist led to the discovery of the Coal-measures; and to the possibility of making a channel-tunnel.

Mr. J. T. Stobbs said that *Anthracomya Phillipsi* was found above the No. 1 Rhondda coal-seam, near the base of the Pennant Grit and near the top of the true Coal-measures. It was found throughout the Midland coal-fields in that position, and also in Durham. Unfortunately, in the Radstock series, worked in Somersetshire, overlying the Pennant Grit, these mollusca did not exist, and the only possible help must come from plants. He (Mr. Stobbs) had no doubt that, as research went on, mollusca, both freshwater and marine, would be found in every coal-field; and a knowledge of their distribution would become a necessary part of the equipment of every mining engineer.

In reply to Mr. J. Dickinson, if fossils are of any use as an indication of horizons in the Coal-measures, then, it is known that the Coal-measures in Durham from the uppermost beds to the Brockwell seam, are the equivalents of the Coal-measures in Lancashire, from near the base of the Ardwick beds to the Arley mine, respectively.

Mr. Gibson's remarks might be punctuated with comment and interrogation, but it appeared that, whilst he attached importance to marine bands as guides in stratigraphy, he was yet sceptical as to the value of the freshwater molluscs. The fact must be emphasized, however, that the scheme tabulated in this paper was not challenged either as to sequence or distribution over the coal-fields from Northumberland to South Wales; and amidst all the side-issues raised by Mr. Gibson, that fact must not be lost sight of, as it was of primary importance.

He (Mr. Stobbs) regretted that Mr. Gibson had reverted to the use of the Upper, Middle and Lower divisions of the Coal-measures, as it was a mistake to think that they "satisfied the stratigraphist and the practical man." So long as the lines of demarcation between these divisions had not the same significance in all the coal-fields, they were a delusion and a snare.

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There was a touch of irony in Mr. Gibson's re-adoption of these terms, as in the *Memoirs of the Geological Survey of England and Wales: The Geology of the North Staffordshire Coal-fields*, prepared under the direction of Mr. Gibson and published this year, it was evidently found impracticable to use them. For practical mining work and for stratigraphy, as proved in numerous instances, these divisions were too thick to be of real help and value.

Whatever assistance, in future, might be rendered by the geologist to the mining engineer, it could be asserted that, up to the last decade, nearly all the difficult problems of the coal-fields had been unravelled by the mining engineer, and the work that he had accomplished, without any of the powerful aids of palæontology, was remarkable for its accuracy. Help, however, would not be long withheld, for the Carboniferous system was now rapidly yielding to those zonal methods, which were the warp and woof of modern stratigraphy; and it would be strange, indeed, if the Coal-measures alone, of all sedimentary rocks, were to constitute an exception to the general application of those methods.

The PRESIDENT (Sir Lees Knowles, Bart.) moved a vote of thanks to Mr. Stobbs for his interesting paper.

Mr. JOHN GERRARD seconded the resolution, which was cordially adopted.

Mr. W. N. ATKINSON (H.M. Inspector of Mines) proposed a vote of thanks to the Lord Mayor and Corporation of Manchester for the use of the meeting-room; to the President and Council of the Manchester Geological and Mining Society for making the arrangements for this successful meeting; and to the owners of collieries, works, etc., to be visited by the members.

Prof. HENRY LOUIS seconded the resolution, which was cordially approved.

Mr. H. C. PEAKE (Past-President) moved a vote of thanks to the President for his services in the chair.

Mr. J. S. MARTIN (H.M. Inspector of Mines) seconded the resolution, which was cordially approved.

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The following notes record some of the features of interest seen by visitors to collieries, works, etc., which were by kind permission of the owners, open for inspection during the course of the meetings on September 13th, 14th, 15th and 16th, 1905:—

ATHERTON COLLIERIES, CHANTERS PITS.

No. 1 Pit.

The No. 1 and downcast pit is 14 feet in diameter. Coal is wound at this pit from the Seven-feet, the Five-feet or Trencherbone and the Yard mines. The shaft is sunk to the Arley mine, which is reached at a depth of 1,824 feet, and passes through the Seven-feet mine at 591 feet, the Five-feet mine at 1,119 feet and the Yard mine at 1,455 feet. The seams dip to the south at a gradient of about 1 in 5. To save time in winding and to avoid hooking-on at an intermediate point in the shaft, the coal from the Seven-feet mine is brought down to the Five-feet mouthing by means of a steep tunnel, rising towards the dip.

One cage winds coal from the Five-feet mouthing at a depth of 1,119 feet, and the other from the Yard mouthing at a depth of 1,455 feet. To accomplish this object, the flat drums of the winding-engine are made of unequal diameter. The drum for the Five-feet mine cage is 10 feet in diameter, while the drum for the Yard mine cage is 13 feet 1 inch in diameter. To counterbalance this, the cage on the small drum weighs 28 cwts. more than the other cage. The double-decked cages hold two tubs of 8 cwts. capacity in each deck. The shaft is fitted with wooden conducting rods as, owing to the room taken up by pump-rods in the shaft, space would not permit of wire-rope guides being used.

The pumping-engine, working at the pit-top, has a cylinder 24 inches in diameter by 48 inches stroke. It has two lifts, one 11 inches in diameter from the Seven-feet mine to the Six-feet mine, and the other lift, 15 inches in diameter, from the Six-feet mine to the surface.

The winding-engine was erected in 1904, at the back of the old engine. The cylinders, 22 inches in diameter by 54 inches stroke, are fitted with Corliss valves, the point of cut-off being controlled by a governor. The differential drums are fitted with post-brakes, and there is a safety overwinding gear.

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The lattice-steel headgear was erected in 1904 to replace an old wooden one.

The pit-top is fitted with the Beien kep-arrangement, by which the keps or catches can be withdrawn from under the cage while the weight of the cage rests on them.

There is a small electric plant, used for lighting purposes only, supplying about 600 lamps at the top and bottom of the pit.

The washery, on the Coppée principle, is capable of dealing with 600 tons per day.

There are six boilers, 30 feet long and 8 feet in diameter, worked at a pressure of 100 pounds per square inch.

No. 2 Pit.

The No. 2 and upcast pit is 16 feet in diameter. Coal is wound at this pit from the Arley mine at a depth of 1,800 feet.

The double-decked cages hold two tubs of 9 cwts. capacity in each deck. The shaft is fitted with wire-rope guides.

The winding-engine has cylinders 28 inches in diameter by 60 inches stroke, fitted with Cornish valves and expansion-gear. The conical drum ranges from 16 to 20 feet in diameter.

The fan, of Waddle type, is 45 feet in diameter. It is at present running at 50 revolutions per minute and exhausting about 200,000 cubic feet of air per minute with a water-gauge of 3¼ inches. The fan-engine has a cylinder 28 inches in diameter by 48 inches stroke, fitted with Corliss valves and a condenser.

The air-compressor, of the Riedler two-stage type, is capable of compressing 3,350 cubic feet of free air per minute to a pressure of 70 pounds per square inch. The compound steam-cylinders are 21 inches and 36 inches in diameter respectively, and the compound air-cylinders, 20 inches and 33 inches in diameter respectively, by 48 inches stroke, fitted with Corliss valves, an intercooler for the air and a Wheeler surface-condenser. They are also fitted with a Whitmore combined air-and-speed governor, by which the speed of the engine varies exactly with the quantity of air required. There are two small Ingersoll-Sergeant compressors, held as a stand-by, capable of compressing about 1,000 cubic feet of free air per minute to a pressure of 60 pounds per square inch. The compressed air is used for pumping, hauling and coal-cutting.

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There are six Lancashire boilers, 30 feet long by 8 feet in diameter, worked at a pressure of 100 pounds per square inch. A Green economizer, with 360 pipes, is used for heating the feed-water.

DOUGLAS BANK COLLIERIES.

Shafts.—There are two shafts, each 1,971 feet deep. The downcast or south pit is 16 feet in diameter for a depth of about 1,500 feet, and 11 feet in diameter below that depth. The upcast or north pit is 16 feet in diameter throughout. Coal is wound from both shafts. In the south pit, one cage goes to the Pemberton mouthing, a depth of 543 feet; and the other cage goes to the Wigan mouthing, a depth of 1,125 feet. In the north pit, the cages run to the Yard and Orrell mouthings, the depths being 1,797 feet and 1,971 feet respectively.

The cages have each three decks, with two tubs in each deck, each tub holding 7¼ cwts. of coal. The three decks are changed separately at the surface, but at the pit-bottoms, the top and bottom decks are changed simultaneously at separate levels, and the middle deck is changed from the same level as the top deck. Self-acting drop-cages supply the lower decks. There are three wire-rope conductors to each cage, each 1¼ inches in diameter. Ormerod safety detaching-hooks are fitted to each cage, and, in addition, extra safety-catches are erected in the headgear. Catches or keps are used at the surface and belowground, and are worked by the banksmen and hookers-on respectively.

Boilers.—There are 10 boilers, 5 at each pit, and they are connected by steam-pipes. At the north pit, there are 5 Lancashire boilers, each 30 feet long and 8 feet in diameter, working at a pressure of 100 lbs. per square inch. At the south pit, there are 3 Lancashire boilers, each 30 feet long and 8 feet in diameter, working at a steam-pressure of 100 pounds per square inch; and 2 Lancashire boilers, 30 feet long and 7 feet in diameter, working at a pressure of 65 pounds per square inch. All the boilers are hand-fired, and the boilers, 8 feet in diameter, are fitted with the Hawksley forced-draught arrangement. The boilers are fed by water from the condensers of the fan-engine, forced into the boilers by a Bailey-Davidson force-pump at each pit.

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Winding-engines.—The winding-engine at the south pit has two horizontal cylinders, each 28 inches in diameter and 5 feet stroke, fitted with Eatock balanced-wedge slide-valves. The drum for the Pemberton cage is 7 feet 7 inches in diameter at the small side and 9 feet 1 inch in diameter at the large side. The drum for the Wigan cage is 16 feet 4 inches in diameter at the small side and 17 feet 8 inches in diameter at the large side.

At the north pit, the winding-engine has two horizontal cylinders, 30 inches in diameter and 5 feet stroke, fitted with Cornish valves and Daglish cut-off and throw-out gear. The drum for the Yard cage varies from 15 feet 11 inches to 17 feet 11 inches in diameter, and the drum for the Orrell cage from 17 feet 7 inches to 20 feet 2 inches in diameter.

Both of the winding-engines are fitted with steam- and foot-brakes. The brakes are of the strap type, with the exception of the south pit foot-brake, where a Burn brake is in use.

Ventilation.—The mine is ventilated by a Walker indestructible fan, 24 feet in diameter and 8 feet wide, with a double inlet and an anti-vibration shutter. The rope-pulley fly-wheel is 18 feet in diameter, and the driven-rope pulley is 8 feet in diameter, each being grooved for twelve cotton ropes, $1\frac{3}{4}$ inches in diameter. The fan produces 280,000 cubic feet of air per minute, at an average engine speed of 44 revolutions per minute and a water-gauge of $3\frac{1}{2}$ inches. The fan is, however, not run at its maximum capacity. The fan is driven by a compound condensing horizontal engine. The high-pressure cylinder is 21 inches in diameter and the low-pressure cylinder 38 inches in diameter, with a stroke of 4 feet. The valves are fitted with Meyer expansion-gear. The condenser, of the jet type, is worked from the cross-head of the low-pressure cylinder.

The condensing water is circulated by a Gwynne engine of the enclosed type, with two single-acting cylinders, 9 inches in diameter by 7 inches stroke, making 210 revolutions per minute. The engine works, by means of a belt-drive, a Gwynne centrifugal pump, which lifts the water to the top of a cooling-tower, 50 feet high, erected over the colliery-reservoir. The reservoir contains 2,250,000 gallons of water. There is a hot well and a cold well in connection with the condensers, made from egg-ended boilers, each 35 feet long and $5\frac{1}{2}$ feet in diameter. A float in

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the hot well, attached to an indicator in the fan-house, records the level of the water in the well.

Haulage.—The endless-rope haulage on the overhead system is driven by three-phase electric motors: four of 50 brake-horsepower and four of 25 brake-horsepower. The motors are of the Brown-Boveri slip-ring type, working at a pressure of 500 to 550 volts. Each motor starts against the load, by means of a main switch and a liquid starter. The 50 horsepower motors run at 600 revolutions per minute, and the 25 horsepower motors at 800 revolutions per minute. The rope-speed in all cases is at the rate of 2 miles per hour. The reduction in speed is obtained by means of gearing, the rope-pulleys being on the fourth motion shaft.

Pumps.—There are two electrically-driven pumps below-ground of 5 brake-horsepower, each lifting 50 gallons of water per minute against a head of 130 feet. The Brown-Boveri motors for these pumps, of the squirrel-cage type, work at a speed of 1,200 revolutions per minute and a pressure of 500 volts. The pumps are of the three-throw vertical Smith-Vaile type.

Preparations are being made, and will soon be completed, for the erection of two electrically-driven shaft-pumps of 15 brake-horsepower. The motors will be of the same type as the haulage-motors. The pumps will be of the three-throw horizontal type, 4 inches in diameter by 6 inches stroke. The vertical lifts will be 381 feet and 570 feet respectively.

A steam pump is placed in the Pemberton mine, near to the shaft-bottom, for forcing water to the surface-reservoirs. The steam-cylinders are 16 inches in diameter by 30 inches stroke, and the pump-rams, 6 inches in diameter by 30 inches stroke, are double-acting. The speed is about 10 revolutions per minute.

The surface-water is caught in the Sawney pit, and is pumped into the same water-reservoir, by means of an engine with a cylinder, 12 inches in diameter by 36 inches stroke, coupled to a pump-ram, 7 inches in diameter by 36 inches stroke, making 56 strokes per minute. The vertical head is 111 feet.

Electric Plant.—The power-plant, in a separate building, consists of two units, each of 250 brake-horsepower when

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worked condensing; the condensing-plant has not yet been erected, but the plans are now completed.

There are two enclosed, inverted, vertical compound Bellis-and-Morcom engines, with two cylinders, and forced lubrication to all the bearings.

The three-phase Brown-Boveri generators are direct-coupled to the engine-shaft. The exciters are also worked on the same shaft. The speed of the engine is 400 revolutions per minute. The current has a pressure of 550 volts, and a periodicity of 40 cycles per second.

The current from these two units is used for driving the underground motors, a 2 brake-horsepower motor on the surface, which pumps the safety lamp-oil into a service-tank erected above the turning-shop at the end of the lamp-rooms, by means of a small three-throw horizontal pump, and drives, when required, a small wood-turning lathe. The same current lights the pit-eyes, shaft-sidings and motor-houses, and adjacent roads belowground. During coal-winding hours the current is also used for lighting the screens. All lighting is effected through transformers, which reduce the pressure from 550 to 230 volts. By means of change-over switches, the screens are lighted, when the continuous plant is running, by means of the continuous current from the 45 brake-horsepower plant situated in the fan-house. This dynamo is driven by a Ruston-Proctor vertical engine, by means of a leather-chain belt. The dynamo is wound for 230 volts, and the current is used for all arc-lamps on the surface, for lighting the offices, workshops and screens (when required), and for driving the lamp-cleaning machine motor of $\frac{3}{4}$ brake-horsepower and the booster for charging the safety-lamp lighting batteries.

Cables.—The cables from the three-phase plant switchboard to the shaft-bottoms are enclosed in haskinized wood-casing. The power-cables belowground are all three-core steel-tape armoured, and are suspended by leather thongs behind the bar-legs.

Working of Seams.—Eight seams are now being worked to the four pit-eyes, and all are worked on the longwall principle. No coal-cutters are as yet at work, but a three-phase Diamond

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overhead coal-cutter of 30 brake-horsepower is now in course of construction. It will cut in the Hoo cannel on the top of the Pemberton Two-feet mine to a depth of 4½ feet. The machine is expected to be at work in October of this year; and if successful, other similar cutters will be introduced.

A Grant electrically-driven rock-drill is used for drilling the holes in a tunnel being driven through the measures, rising 1 in 3. It is driven by a three-phase Brown-Boveri motor of 5½ brake-horsepower.

Screening-plant.—The coals from both pits gravitate to one point, and are there raised by a creeper to a sufficient elevation to enable them to run to four tipplers. The coal passes from the revolving tipplers to shakers, and is sorted into the following classes:—No. 1: slack, nuts and round; Nos. 2, 3 and 4: slack, nuts or filberts (as required), and cobbles and round; and No. 4 is also fitted with a small side-shaker for making a smaller class of nuts. From the shaker, the coal passes to the picking-belts, each 50 feet long: and hence by means of a Swift-and-House scraper-lowering shute into the wagons.

The dust is taken from the slack, and delivered on a canvas belt, which carries it on to a reversible belt, and this in turn delivers the dust to the north or south pit boiler elevator belt, as required.

Any small coal made on the belts, in passing over the belt-end screens, falls upon a suspension-belt fixed under the screen-stage and over the various lines of wagons and at right angles thereto, from which it is delivered upon the reversible belt as above described.

The pickings from the coal are also placed upon the reversible belt, through small shutes, and, consequently, all coals used at the boilers are automatically carried thither by means of the various conveyor-belts.

The dirt wound from the pits is taken to the dirt-tip by means of an endless-rope haulage, worked by the screening-engine and controlled by a separate clutch. This engine has two cylinders, each 12 inches in diameter by 30 inches stroke, making 84 revolutions per minute.

Each belt, each lowering-shute, each shaker and each creeper, is controlled by means of its own clutch.

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NEW MOSS COLLIERY.

There are two shafts with horizontal tunnels to the Saltpetre and Black mines, worked at depths of 2,700 to 3,300 feet. An exploration-tunnel at a depth of 1,359 feet, and a staple-pit, 300 feet deep, proved a fault, with a throw of 1,245 feet, and the Roger and Great mines. There is a level-tunnel, at a depth of 1,530 feet, to the Roger mine on the west of the shafts; and a level-tunnel, at a depth of 2,268 feet, to the Roger mine on the east of the shafts. The Roger mine, 5 feet thick, is being worked by the longwall method, at depths varying from 1,410 to 2,580 feet.

No. 1 Shaft.—No 1 shaft is 2,820 feet deep and 16 feet in diameter, and at present coal is wound from the mouthing at a depth of 1,530 feet. The horizontal winding-engine, with two cylinders 36 inches in diameter by 5 feet stroke, is fitted with Daglish cut-off gear and a drum 16 feet in diameter. Locked-coil ropes, 4¼ inches in circumference, are used. The cage, with three decks, carrying six tubs and 3 tons of coal, is wound from a depth of 1,530 feet. The wrought-iron headgear is 80 feet high, and the pulleys are 16 feet in diameter.

There are ten steam-boilers, five working at a pressure of 120 pounds per square inch, and five at 65 pounds per square inch. The Green economizer has 704 pipes.

The hauling-engine, with two cylinders, 26 inches in diameter by 4½ feet stroke, is geared 9 to 1, and drives two strap-ropes, 4,275 feet long, for the north and south brows respectively.

The north-brow drum, with a strap-pulley, 10 feet in diameter, and a brow-pulley, 8 feet in diameter, hauls 600 tons of coal per day up a brow, 2,980 feet long, and at an average inclination of 1 in 3 or 19 degrees. The approximate load of coal on the rope is 21 tons. The rope runs under the tubs (each holding 10 cwts.) spaced, in sets of three tubs, 210 feet apart.

The south-brow drum, with a strap-pulley, 10 feet in diameter and a brow-pulley, 8 feet in diameter, hauls 700 tons of coal per day up a brow, 1,680 feet long, and at an average inclination of 1 in 5 or 11½ degrees. The approximate load of coal on the rope is 14 tons. The rope runs under the tubs (each holding 10 cwts.) spaced, in sets of three tubs, 120 feet apart.

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A compressor, with two air-cylinders, 21 inches in diameter and steam-cylinders, 22 inches in diameter and 4 feet stroke, supplies compressed air to several underground winches employed to haul up short brows and along the levels.

A direct-current generator, driven by a horizontal engine, with a cylinder 16 inches in diameter by 3 feet stroke, produces 318 ampères at a pressure of 220 volts, or 70 kilowatts, when running at 500 revolutions per minute. The current is supplied to seven motors applied to pumps, 16½ and 17 kilowatts; a chain, 17 kilowatts; a winch, 6 kilowatts; a hammer, 14 kilowatts; a small dynamo, 20 kilowatts, etc.

The No. 1 pit-bottom is protected with side walls and steel girders. There is a lowering table to load the cages at the bottom, independently of the surface-loading.

No. 2 Shaft.—The No. 2 shaft is 2,850 feet deep and 16 feet in diameter; and at present coal is wound from the mouthing at a depth of 2,301 feet.

The horizontal winding-engine, with two cylinders, 36 inches in diameter by 6 feet stroke, is fitted with the Melling-Corliss valve and cut-off gear, and a drum, 18 feet in diameter. Locked-coil-ropes, 4½ inches in circumference, are used. The cage with four decks, carrying eight tubs and 4 tons of coal, is wound from a depth of 2,301 feet in 55 seconds. The wrought-iron headgear, is 90 feet high, and the pulleys are 16 feet in diameter.

There are two Lancashire boilers, 9 feet in diameter and 30 feet long, working at a pressure of 120 pounds per square inch. The Green economizer has 256 pipes. A Sirocco fan with a steel chimney, 70 feet high, is used in lieu of a high brick-built chimney.

The No. 2 pit-bottom is protected with side walls and steel girders, and wrought-iron plates are used instead of arching. An improved lowering-table and balance is used suitable for a four-decked cage.

Screens.—There are six picking-belts, two conveyors and three shaking-screens.

Workshops.—The workshop, 168 feet long by 38 feet wide, is fitted with a travelling crane, and the machinery is driven by

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a horizontal engine, with a single cylinder 13½ inches in diameter and 22 inches stroke. The shops are fitted with lathes, a pneumatic hammer, a planing-machine, and drilling, slotting, shaping and other machines. There are six blacksmiths' hearths.

PENDLETON COLLIERY.

Pendleton colliery is situated in Pendleton, near Manchester. The colliery is a very old one; the sinking of the present two shafts was commenced in 1837, and the Albert and Crumbouke mines were reached in 1840.

During the sinking, cast-iron tubbing was inserted where the shaft passed through the old workings in the Worsley Four-feet mine, but in 1843 this tubbing proved too weak to resist the pressure against it, and the water broke in and drowned out the colliery. A powerful pumping-plant was erected, the quantity of water pumped being 2,330 gallons per minute; and ultimately the water was successfully tubbed out, and the getting of coal was resumed about the end of 1846. The large expenditure, however, incurred in overcoming the difficulties had so crippled the then proprietor that the colliery was stopped in 1848. It was acquired by Messrs. Knowles in 1852, and has since been continuously worked.

The pits were originally sunk each 8 feet in diameter: the winding-engine being between them, with one rope in each pit. One pit was used as an upcast, the ventilation being effected by a furnace and underground boilers. In consequence of the original tubbing having failed, the upcast pit was relined in 1871, reducing the diameter of this pit to 7 feet 2 inches for a depth of about 480 feet below the surface. The depth of the shaft to the Rams mine is 1,545 feet and all the workings lie on the dip side. From the shaft, an engine-plane is driven on the full dip of the mine to a distance of about 5,580 feet, the coal below this being won by east and west subsidiary inclined planes. The vertical depth below the surface at which coal is now being worked varies from 3,000 feet to 3,500 feet.

The seam, dipping about 1 in 3, is worked on a modified system of longwall, the modification being requisite in consequence of the steep dip.

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The colliery has been entirely remodelled within the last 20 years, and practically all the machinery both on the surface and underground has been erected within that time.

The vertical winding-engine at the No. 1 pit has two cylinders, 32 inches in diameter and 72 inches stroke, with a plain cylindrical drum, 20 feet in diameter. There are two cages, each carrying six boxes of coal.

The No. 2 or upcast shaft is used for ventilation only. The Walker ventilating-fan, 18 feet in diameter and 5 feet wide, is driven by rope-gearing from a horizontal engine with a cylinder, 19 inches in diameter and 36 inches stroke, and an independent condenser.

There are six Lancashire boilers, 30 feet long by 8 feet in diameter, fitted with Henderson self-cleaning firebars, working ordinarily at a pressure of 80 pounds per square inch.

To supply power underground, there is a Walker air-compressing engine with two steam-cylinders each 38 inches in diameter, and two air-cylinders each 40 inches in diameter and 6 feet stroke, with an independent condenser: the air-pressure being 65 pounds per square inch.

There is in course of erection an additional Walker air-compressing plant, with compound steam-cylinders, the high pressure being 28 inches and the low pressure 52 inches in diameter, with two-stage air-compressing cylinders, 51 inches and 31 inches in diameter respectively, and 5 feet stroke. This plant will be supplied with steam by five double-flued Lancashire boilers, 30 feet long by 8 feet in diameter, fitted with a Green economizer.

The screens are of the jigger-type, with the usual picking-belts loading direct into canal-boats.

The underground machinery comprizes a hauling-engine, hauling up the main engineplane, with two cylinders each 20 inches in diameter and 42 inches stroke, and two drums each 6 feet in diameter. At the subsidiary brows, there are self-contained hauling-engines, that at the west brow having two cylinders each 16 inches in diameter; and that at the east brow, two cylinders each 10 inches in diameter. The level hauling is on the endless-rope quick-travelling system. The signalling is electrical.

The surface-works are lighted by electricity.

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THE LANCASHIRE ELECTRIC POWER COMPANY.

The Lancashire Electric Power Company was formed for the distribution of power throughout the whole of Lancashire, south of the river Ribble, excepting the areas of Liverpool, Bootle, Manchester, Salford, Stockport, and the 2½ miles radius from Bolton town-hall. The mains for carrying current are being laid in duplicate, partly underground, laid in solid bitumen with steel-wire armouring and leaden sheathing for protection, the insulation being paper. The section of copper is 0·1 square inch, three conductors being enclosed in each cable. On another part of the way, the cables are being carried overhead on insulators, the same section of copper being used.

The current is delivered to the mains at a pressure of 10,000 volts on the three-phase alternating system. In the case of large users, the current is taken direct into the consumers' premises, and is there converted to a suitable pressure for use. In the case of small users, a supply is given in bulk to the township authorities, who act as distributors of the current. The distribution is both on the three-phase and direct-current systems, diverse conditions causing it to be advisable to use direct in some cases and alternating in others.

The generating-station is located in Radcliffe, on the banks of the river Irwell, near the Ringley-road station, on a site with an area of 20 acres. The first section of building erected consists of a boiler-house and an engine-room.

The boiler-house contains six Babcock-and-Wilcox water-tube boilers, fitted with chain-grate stokers, each giving an evaporation of 20,000 pounds of water per hour, at a working pressure of 150 pounds per square inch. The boilers are fitted with Babcock internal superheaters, and have a heating surface of 5,800 square feet. The boilers are placed in two rows of three each, face to face, with a firing alley-way between. Above this alley-way are the coal-bunkers, one bunker feeding two opposite boilers. The buildings being situated some 76 feet below the railway-level, the coal is fed by gravity into the bunkers from the railway-siding. The water is fed to the boilers from two Hall feed-pumps, each capable of delivering 12,000 gallons of water per hour. The make-up water is obtained from the town mains. Steam from the boilers is taken in a ring-main in the boiler-house, from which connections are taken to each of the machines.

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The smoke-stacks are two in number, one for each set of three boilers. They consist of a base of 12 feet; and a steel shell, 150 feet high; they are lined with fire-brick to a height of 112 feet, the internal diameter being 10 feet.

There are four machines, each driven by vertical Curtis turbines, the alternators, each of 1,500 kilowatts, being placed above the turbine and on the same spindle. They run at 1,000 revolutions per minute, 11,000 volts, and give a three-phase current at 50 periods per second. The machines have an overload capacity of 50 per cent. for ½ hour, and of 100 per cent. for a momentary overload. There are four stages of expansion in the turbines, and the vacuum is about 28 inches throughout. One of the interesting parts of this turbine is the method of supporting the footstep-bearing: the spindle rotates in a cup, through the centre of which water is pumped at a pressure of 400 pounds to the square inch, thereby forming a thin skin of water which keeps the spindle from the face of the cup. This water-skin is about 0·001 inch thick. The water is raised to this high pressure by means of two three-throw pumps, each driven by a motor of 7½ horsepower, and rotating at 15 revolutions per minute: one of them being a stand-bye. The water-accumulator has sufficient capacity to provide water for all the turbines for ¼ hour should the pumps fail for any reason. Each turbine is connected directly to a vertical Mirrlees-Watson surface-condenser, each capable of dealing with 30,000 pounds of steam per hour, and having a cooling-surface of 3,500 square feet. The Edwards three-throw air-pumps are motor-driven, at a speed of 160 revolutions per minute. Circulating water is taken from the river by means of four Gwynne centrifugal circulating pumps, each capable of delivering 160,000 gallons per hour against a head of 26 feet. The pumps are primed by a dry-air pump, the vacuum being maintained by means of gravity by using a tank placed higher than the water-barometer. This pump is also used as a means of increasing the vacuum in the condensers, by equalizing the flow of circulating water. An overhead travelling-crane, capable of lifting 25 tons, is actuated by motors: the span being 47½ feet and the total lift 39½ feet.

The alternators are excited by means of separate exciter-sets, three in number, each of 150 kilowatts, consisting of Allans engines with British Thomson-Houston dynamos, running at

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420 revolutions per minute and a pressure of 220 volts. The engines are run non-condensing, the exhaust-steam passing through a heater for the boiler feed-water.

The switchboard is mounted on a gallery, and is of the remote-control type. The main switches are operated by motors controlled from the main switchboard, upon which only low-tension current is taken. There are two sets of omnibus bars, divided by a sectionalizing switch. The switchboard consists of panels, each generator and each circuit having a panel to itself. The generator-panel has a voltmeter, an ammeter, and a power-factor indicator, together with the necessary trip-switches for operating the motors. Each feeder-panel has an ammeter and a wattmeter. Besides these, there is a low-tension board for operating the auxiliary plant in the station.

There is an electric locomotive crane capable of lifting 10 tons, and it can be used for shunting and other work on the siding.

MANCHESTER CORPORATION ELECTRICITY-WORKS, STUART STREET.

System.—Three-phase alternating currents, with a frequency of 50 cycles per second, are generated at the main power-house at the extra high-pressure of 6,500 volts, and are transmitted at this pressure to the sub-stations. The current from the sub-stations is supplied at a pressure of 500 to 550 volts to the tramways, and at 420 and 210 volts for lighting and power-purposes.

Coal-supply.—A special railway-siding connects the Stuart Street works with the Lancashire and Yorkshire railway. The railway-trucks are emptied direct into coal-hoppers on the siding, and thence the coal is carried by electrically-driven conveyors to the bunkers over the boilers. The coal is weighed before it is deposited in the main hoppers, and it will also be automatically weighed and recorded by means of measuring-boxes attached to the shoots leading to the boiler-furnaces.

Buildings.—The buildings consist of two boiler-houses, chimneys, pump-rooms and engine-houses. They are of steel framework, filled in with brick-walls, faced with white-ended bricks and dressings of Ruabon bricks and Yorkshire stone.

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Boilers.—There are twenty-four double-drum Babcock-and-Wilcox water-tube boilers, each capable of evaporating 12,000 pounds of water per hour at a pressure of 170 pounds per square inch; and twelve Babcock-and-Wilcox water-tube boilers, each capable of evaporating 20,000 pounds of water per hour at a pressure of 200 pounds per square inch.

Feed-pumps.—City water is used. Three Weir compound duplex steam-pumps are each capable of delivering 15,000 gallons of water per hour against a steam-pressure of 170 pounds per square inch.

First Engine-room.—There are six main three-phase alternator sets of 1,500 kilowatts each. There are four overhead electrically-driven travelling-cranes of 20 tons capacity.

Each of the main engine-sets consists of a Yates-and-Thom vertical cross-compound engine of 2,500 indicated horsepower, running at 94 revolutions per minute; and a three-phase alternator of 1,500 kilowatts, generating current at a pressure of 6,500 volts with a periodicity of 50 cycles per second. The high-pressure and low-pressure cylinders of the engine are 36 inches in diameter and 71 inches in diameter respectively by 3½ feet stroke. The cylinders are steam-jacketted, and are fitted with Dobson-Corliss valve-gear. The main shaft is 22 feet long and 25 inches in diameter in the main bearings. The cast-iron fly-wheel, built up in four sections, weighs about 70 tons. The generator is placed between the high-pressure and low-pressure cylinders, and is of the revolving-field type, the pole-pieces being mounted on the external periphery of the fly-wheel of the engine and revolving in the stationary armature, with star-connected windings.

A special feature in connection with the regulation of the speed of these engine-sets is that the engine-governor can be controlled from the switchboard-gallery by means of an electric motor. The barring-gear for starting the engines is also electrically driven.

Second Engine-room.—There are two triple-expansion engines of 6,500 horsepower, and two three-phase alternator sets of 3,750 kilowatts.

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All the engines are run condensing, and cooling-towers are erected for the purpose. The engines develop a total of 28,000 horsepower.

Switchboards.—Two main high-tension switchboards are each arranged to control three high-tension three-phase generators, one high-tension three-phase motor and seven high-tension feeders; and another main switchboard controls the two main sets of 3,750 kilowatts, etc.

Cable-subway.—The cable-subway accommodates 30 three-core cables, distributors, etc. The cables are carried on brackets fixed on each side of the subway. The subway is 10 feet high, 5 feet wide and 2,820 feet long.

Cables.—About 170 miles of cables are required for connecting the sub-stations with the generating-station.

THE VICTORIA UNIVERSITY OF MANCHESTER: THE MANCHESTER MUSEUM.

The museum takes cognizance of natural history in a wide sense, with special reference to mineralogy, geology, zoology and botany, without, however, excluding such subjects as archæology and anthropology. The nucleus of the present museum was furnished by the collections formerly belonging to the Manchester Natural History Society, founded in 1821, and by those of the Manchester Geological and Mining Society, founded in 1838.

The special geological and palæontological collections comprize:—The "David Forbes" collection of minerals and rock specimens; the "Waters" collection of fossils; the "Boyd Dawkins" collection of fossils, minerals and prehistoric remains; the "Williamson" collection of Yorkshire fossils and specimens of coal; the "Cash" collection of sections of Carboniferous plants; the "Kay-Shuttleworth" collection of Carboniferous fossils; the "Hick" collection of sections of Carboniferous plants; the "George Wild" collection of Carboniferous fossils; the "Melvill" collection of Eocene mollusca; the "Darbishire" collection of Tertiary shells, from the raised beach

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at Uddevalla; the "Cairns" collection of fossils, chiefly from the Crag, the Cretaceous and the Carboniferous Limestone; the "Bird" collection of fossils; the "Toulmin Smith" collection of Cretaceous sponges; the "Lightbody" collection of fossils; and the "Manning" collection of fossils.

THE MANCHESTER SHIP-CANAL.

The entrance to the Ship-canal at Eastham is 19 miles from the bar at the mouth of the river Mersey, and the access is from the sea *via* the lower estuary. The access-channel has been excavated to a depth of 20 feet below the Old Dock-sill, Liverpool, so as to give access to the canal at any state of the tide. The canal is 35½ miles in length, and the principal docks are at Manchester, a distance of 50 miles from the sea.

The canal between the entrance at Eastham and the docks at Manchester has been excavated throughout to a depth of 26 feet, which depth is maintained by dredging, but in the tidal portion of the canal between Eastham and Latchford (21 miles), the available depth varies from 26 feet to 33 feet, according to the state of the tide. The bottom-width at the full depth is 120 feet, with the following exceptions:—(*a*) At the curve at the Weaver outfall, the width at the full depth is 180 feet; and at the bend at Runcorn, approaching the Runcorn railway-bridge, the width is 150 feet. (*b*) For a part of the length between Latchford locks and Partington coal-basin (about one mile in all), the bottom-width is at present only 80 to 90 feet, and large vessels are not allowed to pass each other on that portion of the canal. (*c*) From Barton aqueduct to the Manchester docks, the bottom-width is 170 feet.

The tidal portion of the Ship-canal, from Eastham to Latchford locks, or 21 miles, is maintained at 14 feet 2 inches above the level of the Old Dock-sill, Liverpool (or 9 feet 6 inches above Ordnance datum, or mean sea-level), giving a depth of 26 feet of water.

The three locks at Eastham form three separate entrances, which are open to the river-level, whenever the tide rises more than 14 feet 2 inches above the level of the Old Dock-sill, and when the tide is below this level, access is obtained by means of the locks.

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The lower sill of the large lock (600 feet by 80 feet) is 23 feet below the Old Dock-sill, the upper sills of all the large locks being 28 feet below the normal water-level. A vessel can be passed through the largest lock in 8 minutes or less. The intermediate lock is 350 feet long by 50 feet wide, and the small lock, 150 feet by 30 feet. The width of the canal at Eastham locks is 315 feet.

Mount Manisty, on the north side of the canal, was formed by the material excavated from the rock-cutting during the construction of the canal, and is available for ballasting vessels.

The dimensions of the Manchester Docks are:—No. 1, 700 feet by 120 feet; No. 2, 600 feet by 150 feet; No. 3, 600 feet by 150 feet; No. 4, 560 feet by 150 feet; No. 5, 980 feet by 750 feet; No. 6, 850 feet by 225 feet; No. 7, 1,160 feet by 225 feet; No. 8, 1,340 feet by 250 feet; and No. 9, 2,700 feet by 250 feet. The dock-equipment includes 52 hydraulic, 57 steam and 81 electric cranes, with a radius of from 16 to 40 feet, capable of lifting from 1 to 10 tons to a height from rail-level of from 13 to 59 feet; a 30 tons steam crane; 35 locomotives; 6 floating pontoons of a dead-weight capacity of 800 tons each, and all modern appliances for giving quick despatch to vessels. There is also a pontoon-shears capable of dealing with weights up to 250 tons, with a lift of 21 feet.

There is a range of thirteen single-floor, one two-floor, six three-floor, five four-floor, and twelve five-floor transit-sheds, fitted with modern appliances; also thirteen warehouses, seven storeys each, fitted with 27 friction-hoists worked by gas-engines; and in Trafford Park, four single-floor warehouses, each 300 feet by 100 feet. The docks, quays, sheds and warehouses, are lighted by electricity, and there are 34 hydraulic and 16 electric capstans on the quays. Bonded accommodation is also provided.

The total traffic since the opening of the canal in 1894 has been as follows:—1894, 925,659 tons; 1895, 1,358,875 tons; 1896, 1,826,237 tons; 1897, 2,065,815 tons; 1898, 2,595,585 tons; 1899, 2,778,108 tons; 1900, 3,060,516 tons; 1901, 2,942,393 tons; 1902, 3,418,059 tons; 1903, 3,846,895 tons; and 1904, 3,917,578 tons.

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BRITISH WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY, LIMITED: TRAFFORD PARK WORKS, MANCHESTER.

The British Westinghouse Company own about 150 acres of land at Trafford Park; 55 acres of this are enclosed within the buildings, while 32 acres are roofed in. There are altogether nine main buildings, including the offices. The machine-shop, 1,000 feet long by 430 feet in width, is divided into five bays; next to this is the steel-foundry; beyond which is the brass and malleable-iron foundry, with pattern-shop and stores. There is a box-factory and a paint-shop on the right of the machine-shop. A noticeable feature of the works is the excellent lighting and ventilation.

The principal machine-shop is divided into five bays, and the whole structure is of steel. The largest lathe will take in work 125 inches in diameter, while the length between the centres is 45 feet. There are 10 feet to 28 feet boring-mills, 10 feet to 14 feet planing-machines, large radial drills, a three-spindle vertical milling-machine and double-headed two-spindle horizontal boring-machines.

In the steel-foundry, there are 20 tons open-hearth Wellman-Seaver rolling-furnaces of the most recent design; two 50 tons and one 10 tons overhead electric travellers; five air-hoists and jib-cranes; cutting-saws; annealing and drying ovens; and other usual appliances. The laboratory-arrangements are complete, chemical and mechanical tests being carried out in the usual way. There is a 100,000 pounds testing-machine.

The iron-foundry is somewhat larger than the steel-foundry. There are two Whiting cupolas, with special weighing machinery, by which the proper mixture of pig is obtained. The cupola-blast is generated by two Sturtevant blowers, driven by an induction-motor. Iron-castings, up to 30 tons in weight, are made.

In the boiler-house, there are six Babcock-and-Wilcox boilers, each having 4,020 square feet of heating-surface, steam being generated at a pressure of 160 pounds per square inch. These boilers are mechanically fired by Roney stokers, driven by a Westinghouse steam-engine. There are three air-compressors of great capacity.

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The tunnel under the machine-shop is extended to the foundries and pattern-shop.

Electrically-driven cranes are used throughout the works; and electricity is the chief motive power. In the large machine-shop, there are four 50 tons cranes, seven 10 tons cranes, and five 5 tons cranes. There are two 20 tons cranes in the transformer department. In each of the main aisles of the steel- and iron-foundries are two 50 tons cranes and four 10 tons cranes.

A Westinghouse single-phase electric railway runs round the works.

MESSRS. W. T. GLOVER & COMPANY, LIMITED.

Almost every type of cable was shown in the process of manufacture, including cables for colliery and mine working.

The main building, consisting of six large parallel bays, contains large stranding-machines capable of laying up in one operation as many as 91 strands of wire, papering machines for putting on the wellknown Diatrine insulating-paper, laying-up machines for the purpose of cabling up several cables into one multicore cable, armouring machines, etc. There are several large hydraulic lead presses, capable of covering cables up to 4 inches in diameter: the lead being forced on while in a semi-plastic state through cores and dies.

The test-tanks and testing machinery are capable of applying pressures up to 72,000 volts on the cables. The Claremont hydraulic testing-tank is used to test the "waterproofness" of the lead-covered paper cables, pressures being applied, up to 100 pounds per square inch, to the cable under water. In the various large outbuildings are installed forcing machines for the manufacture of bitumen-cables, paper-serving machines, machines for covering wires and cables with rubber, and an indiarubber-mill, for the cleaning and drying of raw indiarubber and the mixing and calendering of the various indiarubber-compounds used in vulcanized indiarubber-cables.

The whole of the machinery is electrically driven.

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PART VII. VOL. XXIX.

TRANSACTIONS

OF THE

MANCHESTER GEOLOGICAL & MINING SOCIETY.

EDITED BY

THE HONORARY SECRETARY.

SESSION 1905-1906.

PUBLISHED AT THE ROOMS OF THE SOCIETY,
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MDCCCCVI.

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MANCHESTER GEOLOGICAL AND MINING SOCIETY.

ORDINARY MEETING,
HELD AT THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
JANUARY 9TH, 1906.

MR. HENRY BRAMALL, PRESIDENT, IN THE CHAIR.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

CAPTAIN HENRY VAUGHAN HART-DAVIS, Bridgewater Collieries, Walkden, near Manchester.

Mr. WILLIAM YOUNG, Hindley Field and Victoria Collieries, Bickershaw, Wigan.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, LONDON, 1905.

Mr. WILLIAM WATTS, Delegate of the Society to the meeting of the Corresponding Societies of the British Association for the Advancement of Science, read his report as follows:—

Agreeably with the request of the Council of the Manchester Geological and Mining Society, I attended the meetings of the Delegates of the Corresponding Societies of the British Association for the Advancement of Science, held at Burlington House, London, on October 30th and 31st, 1905.

The number of affiliated societies is 70, representing 25,000 members spread over the United Kingdom. The meeting was presided over each day by Dr. A. Smith Woodward, and was a complete success, both as regards the number of members present and the interest taken in the proceedings.

In his opening remarks, the President pointed out the advantages that members of local societies have in rendering assistance to the Association generally by original research and observation of phenomena in districts wide apart, and available only to men moving in them day by day for many years. Observations made in this way and covering a large area led to more definite work being done, especially when the results were carefully tabulated. Every corresponding society should aim at original work and lend assistance where it is required by organization and centralization, and

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by the help of museums and libraries in which specimens and books of reference can be kept. The British Association is always willing to assist local societies striving to do exhaustive work, and it would be a good thing if some substantial inducement could be offered to country societies to vie with each other in bringing before the sectional meetings of the Association scientific, literary and antiquarian matter worthy of notice. It is impossible for one man to know everything, or one country, section or tribe to possess all the knowledge of the human race, but as knowledge is the wealth of the mind, the more it contains the richer and happier the race becomes. It was urged that local societies would act wisely in setting before themselves the object of some definite work, and strive to perfect it to the highest degree within its limits. Concentration is a power in the mind, and gains force by application, as water gains power by being raised, and steam by being cooled. There are many things which local societies can do in detecting and recording local phenomena, a knowledge of which adds to the pleasure of human life as the dawn of day adds to the pleasure of a lost wanderer in a dark night.

The tendency of picnics in societies was alluded to, and whilst it was admitted that rambles were generally popular and gave members an opportunity of knowing each other, they were not productive of much scientific work; but they encouraged members to join societies and to become contributors to the funds which enabled them to exist and publish their proceedings.

One delegate informed the Conference that his society refused all invitations of hospitality in order to devote all the available time to the scientific work undertaken for the day. Your delegate, however, is not prepared to recommend a course so rigid, especially after a long walk in a moorland glen, with the prospect of a welcome repast in the house of a genial host. It is true that man does not live by bread alone, but healthy food taken when required refreshes and strengthens the scientific mind.

Dr. Martin read a deeply interesting paper on treasure-trove, mainly with regard to the legal ownership of the articles found, and the claims of the finder with regard to them. He contended that articles found on land should go to the landowner, but that the finder should be liberally remunerated for collecting and honestly producing them. One must discriminate, however, between lost property and treasure-trove, and the value of articles, whether gold, silver or finds of great antiquity. There is a statute of limitations with regard to treasure-trove, but it is little known; and it should be the duty of Corresponding Societies to assist in preserving and recovering treasures where they are supposed to exist, and to present them, without alteration, to the local or British Museum for permanent preservation, and exhibition for educational purposes. The more ancient and valuable articles, it was contended, should be forwarded to the British Museum, as national property, as one is not sure of the permanency of local museums nor of the means of protecting and preserving articles of extreme value.

With regard to treasure-trove, six years is the statutory limit enabling the Government to claim it. It is contended that in leases of land and buildings, clauses should be inserted to preserve all treasure-trove articles and to make it penal not to produce them when found. Workmen should be advised to present all ancient articles to the owner of the land or other person in authority over the works, by whom they should be liberally rewarded

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In preserving treasure-trove union is doubtless desirable, and every member of every society should assist in recovering and preserving it. Indeed, it would not be amiss if each corresponding society would make known to its members the gist of the law in reference to treasure-trove.

A paper was read on "The Law of Copyright as affecting the Proceedings of Scientific Societies": it evoked an interesting discussion as to the difficulty involved in legislating on the subject. Copyrights are of two kinds, namely, private and public. A person writing a book, play or music, has no difficulty in protecting it, but it is difficult to protect a lecture given in public *viva voce*, although it calls forth the knowledge and genius of the lecturer just as much as a book or play written in the quietude of home. The lecturer, however, can protect himself by having his lecture printed before delivery, but this is not always convenient, and if in the inspiration of a moment he makes valuable *viva voce* remarks, which draw upon the experience of a lifetime, they may be appropriated by others to their own advantage.

In the opinion of your delegate, lectures should be made copyright property, and not publicly used unless the author desired publication; but their usefulness in spreading knowledge would be less, and the classes for whom the information was intended would be the sufferers. Special legislation for the protection of lectures, speeches, poetry and songs is difficult to secure; but it seems only fair that literary and scientific matter should not be pirated by writers and critics who have a faint knowledge of the subjects criticized, unless permission to submit the matter is previously obtained. Criticism is most valuable when it comes from a writer who possesses superior knowledge, but not otherwise; and authors should be protected from the unfair comments of ignorant scribblers.

Prof. Boyd spoke with reference to the wilful extinction of flowering plants and many kinds of trees, and urged that every local society, through its members, should do all that was possible to protect and preserve them.

The spread of population, inroads made by the sea, occasional devastation made by floods, landslips, reclamation of land for cereal and other cultivation, added to climatic changes, are more or less destructive of rare plants, but protection is most required from the ravages made by man in the thoughtless destruction of plant-life. The environment of London has suffered fearfully from the extinction of plants, and mainly the flowering species, especially the brighter and more cheerful kind. Within a radius of about 20 miles of the Metropolis nearly the whole of the wild flowers producing beautiful blooms are extinct. Collectors are not content to pluck the flowers, but the roots also are torn up, and in the autumn of the year the fruit also is plucked or destroyed, thus preventing fructification even in plants tenacious of life. It is difficult to say what can be done to protect flowering plants and herbs from total elimination from the country. It has been suggested that fruiterers and florists should be compelled to take out licenses for the sale of plants, flowers and saplings, as well as herbs, in order to prevent wilful destruction, and that both a species and a time-limit should be insisted upon. Hot-house plants and many flowers reared by florists and gardeners are privately protected, and it is not difficult to reproduce the kind of flowers and plants in which they deal, but the wild species of plants of all kinds are fast disappearing and need immediate protection to save them.

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Rambles got up by natural history and other societies often assist in extinguishing plants by making collections during their rambles, and carrying away roots, flowers and fruit simply to gratify a taste for a few hours. The evil does not end here. Accounts often appear in the local papers with a list of the plants found, thereby causing others to follow to complete the destruction, when common ones would do for illustration for educational purposes.

"Ministers themselves ha'e been ken'd" to participate in this "unholy rapture" by collecting trees to decorate their school-parties at Christmas. The hollies and young fir-trees suffer greatly; the holly in particular has become rare in the neighbourhood of every large town in the country and bids fair to become extinct in time, especially the berry-producing plant. Parties coming into the country in the spring of the year often return laden with ferns, branches of trees, and young saplings, which are cast away before the day is ended, and irreparable damage is thus done by persons having eyes with little power of seeing, and minds bent on pleasure rather than on the pursuit of knowledge.

The law seems inadequate to protect the plants, and farmers are often helpless, as they have to prove damage before they can secure a conviction, which is difficult, although the last primrose or daffodil may be taken from fields in their sight.

Trespass in search of plants, mushrooms and blackberries, is a frequent complaint made by farmers, and if one of them is bold enough to summon a trespasser, not infrequently damage is privately done to walls, gates and crops afterwards. Your delegate has personal knowledge of this kind of trespass committed with a boldness and impunity bordering on defiance. Wild birds and game suffer from a like cause; larks and thrushes suffer most, although fully 60 per cent. of these birds die shortly after they are caged. The ideal of beauty in many men is abnormally low, and the song of the lark or thrush has no charms of sweetness or melody in the morning light or evening glow.

It is deplorable how little regard is paid to tree-planting in England. There are a few noble exceptions, however, of landowners insisting upon a number of saplings being planted on their estates annually, but there is no law to enforce the example generally, and it is left to individual desire. Trees in the parks and outskirts of many towns show what can be done in forestry with attention and care, and much more could be done in making unsightly places beautiful, healthy and financially sucessful, by judicious planting and arranging for the older trees to shelter and nurse the younger ones during the first few years of tender growth.

On Monday evening, the opening day of the Conference, the delegates were entertained at dinner by the Committee of the Royal Societies' Club, 63, St. James Street, S.W. The function was numerously attended, many notable gentlemen were present, and a most enjoyable evening was spent, which will long remain a pleasing reminder of the first visit to London of the Corresponding Societies of the British Association.

Your delegate has endeavoured to bring before his Society the main points of interest introduced at the Conference, he fully appreciates the honour conferred by your Council in such an appointment, and trusts that the Manchester Geological and Mining Society will do what it can, through its individual members, to help the British Association in its scientific work.

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The PRESIDENT (Mr. H. Bramall) moved a vote of thanks to Mr. Watts for his report, and the interesting information that he had placed before the members.

Mr. JOHN GERRARD (H.M. Inspector of Mines) seconded the motion, which was carried unanimously.

Mr. JAMES ASHWORTH read the following paper on "The Elba and Clydach Vale Colliery Explosions":—

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THE ELBA AND CLYDACH VALE COLLIERY EXPLOSIONS.

By JAMES ASHWORTH.

Although the evidence given at the inquests on the miners killed by the recent explosions at these collieries* did not disclose the precise means by which the explosive mixture of fire-damp and dust and air became ignited, yet it did point out, to the satisfaction of the coroners and their juries, and of H.M. inspectors of mines, the locale of the initiation of both explosions.

In the enquiry into the explosion at the Elba colliery, the verdict of the jury was as follows:—(1) That the cause of death was by an explosion; (2) that the nature of the explosion was fire-damp; (3) that it occurred in No. 4; and (4), in our opinion, the cause was probably a naked light.

In the enquiry into the explosion at the Clydach Vale collieries, the verdict of the jury was as follows:—(1) On the evidence submitted to us we are unanimously of the opinion that the explosion occurred in No. 6 cross-cut of the No. 5 district. (2) We are also of opinion that the explosion occurred in consequence of something happening to David Enoch's lamp; and (3) that no blame can be attached to anyone for the explosion. The jury added the following rider: We recommend the management to spare no effort to enforce Rule 179. [This rule has reference to the giving out to each man of the same safety-lamp, day after day, so far as is practicable.]

The safety-lamps used at both collieries were of the same types, namely, the bonneted Clanny, and the bonneted Jack Davy lamp (generally known as the Cambrian fireman's Davy lamp), and they were of first-class construction.

At the Elba colliery, no open light was found, and the suggestion that the explosion was caused by an open light was

* Elba colliery on January 21st, 1905; and Clydach Vale colliery on March 10th, 1905.

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based on matches being found in a waistcoat hanging in the level near No. 4 heading, and a pipe found in the pocket of a miner's coat, which was also hanging up between Nos. 5 and 6 heading, on the lower side of the level. Two matches and an empty cigarette-box were also found in a waistcoat belonging to one of the men injured by the explosion. All the lamps were found locked, and in apparently good order when recovered.

Mr. J. T. Robson, H.M. inspector of mines, in his evidence is reported to have said that there was gas in No. 5 heading, top hole, that the explosion happened inside of No. 4 heading, that the whole of the gas in No. 3 heading where there was a big fall, was not exploded at the time; that without going to the length of saying that it was utterly impossible that the explosion could have happened with a lamp in apparently good condition, he thought it most highly improbable, and at any rate in this case it did not happen. The lamps were all right. It was highly improbable, for the reason that "invariably these lamps go out as soon as ever they come into contact with an explosive mixture."

At the Clydach Vale enquiry, Mr. F. A. Gray, H.M. inspector of mines, is reported to have said that he approved of the firemen using the Davy lamp and the Clanny lamp on their rounds; that when he saw David Enoch's body at the place where it was found, he was satisfied that the explosion occurred in the No. 5 district; that this was also the conclusion of Messrs. L. Llewelyn, W. W. Hood, D. Hannah and T. Griffiths, and of his assistants, Messrs. J. D. Lewis and F. J. Trump. He thought that the explosion originated in the ignition of gas, and was carried from district to district by coal-dust; and, contrary to the majority of explosions, this one travelled through the return-airway with a great deal of force. The coroner, in summing up, said that everybody was in absolute agreement that the starting point of the explosion was in Daniel Price's district, and that there was only one human being there at the time; and it occurred to him that David Enoch was "doing something to clear the gas when something happened which started the explosion."

Judging from these reports, it appears certain that in the Clydach Vale colliery, as well as at the Elba colliery, a man was

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doing "something" with accumulated fire-damp, probably with the idea of removing it. It is not the least likely that either man would be playing with matches under such conditions, and therefore the only source of flame would be encased in a bonneted Clanny lamp (Fig. 12) at the Elba colliery, and in either a bonneted Clanny or a bonneted fireman's Davy lamp (Fig. 13) at Clydach Vale colliery.

Evidence was given that all these lamps were in good condition when delivered to the men, and that they were not found unlocked. What then initiated these explosions? The first natural conclusion must be that they were caused by the failure of safety-lamps of approved construction to justify their designation of "safety-lamps." To prove circumstantially that the name "safety" is only an alias, when applied to these two patterns of miners' lamps, we need to turn to the finger-prints left behind in the present instances, and compare them with those so distinctly recorded by previous disasters. Thus the admittedly dangerous conditions at the Elba and Clydach Vale collieries were caused by admixtures of air, fire-damp and coal-dust; and as no evidence was given as to the velocity of the ventilating current, it may be assumed that it was much the same in both cases.

FIG. 12.—BONNETED CLANNY SAFETY-LAMP.

For the sake of comparison, the explosions at Allerton Main colliery and Shakerley colliery, may be referred to, as in both cases the only means of ignition was that of the flame within a safety-lamp, and in the latter case the lamp (Fig. 1, Plate XI.) was practically in a quiescent atmosphere. The bonneted Clanny safety-lamps in use at both of these collieries were experimentally tested after the disasters in various velocities of, and mixtures of, fire-damp and air, and in neither case did the lamps fail; but it is to be noted that one factor was omitted from the tests, namely, coal-dust. It is, therefore, clear that the neglect of this factor lessened the value of the tests, and did not afford any proof that these lamps were safe in a dusty mine.

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So long ago as 1852, Mr. James Darlington, a mining engineer when giving evidence before a Governmental Commission, said that many explosions had occurred in collieries which he could only attribute to ignited coal-dust flying off a Davy lamp in which gas was burning.*

In 1879, the writer, when experimenting with Davy lamps in currents of air mixed with fire-damp, found that a mixture of 4½ per cent. of gas in a velocity of 370 feet per minute would burn for a long time within the gauze without the flame passing out of it; but if, in addition, the air were carrying coal-dust in suspension, just as much as it would pick up naturally from the floor, the lamps would pass the flame in 10 seconds and cause an explosion.†

FIG. 13—BONNETED FIREMAN'S DAVY SAFETY-LAMP.

Mr. C. E. Rhodes also made some safety-lamp experiments with coal-dust, and his opinion was, that explosions might be caused much more easily, and at a lower velocity when coal-dust was a factor than when it was absent.‡

The writer does not know of any other experiments that have been made on safety-lamps with coal-dust in suspension in an air-current charged with a low percentage of fire-damp, and as the Royal Commission, appointed to report on Explosions

* *Report from the Select Committee on Coal-mines*, 1852 [509], page 108; and *Trans. N.E. Inst.*, second edition, 1860, vol. i., page 309.

† "Improved Safety-lamps of the Davy and Mueseler Types," by Mr. James Ashworth, *Trans. N.E. Inst.*, 1880, vol. xxix., page 148.

‡ Letter to the author of April, 1905.

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from Coal-dust in Mines, did not touch on this danger the subject has remained almost entirely neglected.

There are, however, other points in the construction and use of safety-lamps which have received very close attention, and although the results of the experiments have been published, they are still very imperfectly understood or observed.

The honour of being the pioneer-investigator of the safety of the details of a safety-lamp, undoubtedly belongs to the noted French mining engineer, Mr. J. B. Marsaut,* and in this he was followed by the Prussian and Saxon Commissions. Each of them made tests on the size of mesh, and of the wire, used in the gauze of safety-lamps, and although they did not all adopt the Davy size of mesh, yet they did agree that a mesh of 784 apertures to the square inch, and made of wire $\frac{1}{60}$ inch in diameter was a firm and reliable covering, and that a Davy gauze, 1½ inches in diameter and about 4 inches high, was a safe and satisfactory protection to the lamp-flame, when exposed to quiescent mixtures of air and fire-damp, or to explosive currents of low velocity.

All experimenters have also agreed, that every increase in the diameter of a gauze above 1½ inches reduces its power of resistance. When glass surrounds the wick-flame, without the interposition of a gauze-covering, practically all are agreed that the best form of gauze to surmount the glass is that of a truncated cone with the smallest diameter at the top (Fig. 2, Plate XI.), that the most dangerous form is the reverse (Fig. 3, Plate XI.), with the largest diameter at the top, and that a gauze, with the addition of a metal-disc with a hole, *a*, in it of the same size as the top of the gauze (Fig. 4, Plate XI.), is equally dangerous.

In another series of experiments, Mr. J. B. Marsaut assumed that the cylindrical glass of a Clanny lamp produced an effect similar to that of a cannon when an explosion occurred within the lamp, and he proceeded to cover the base of the gauze with bands of paper of various widths, thus discovering that the more

* "Étude sur la Lampe de Sûreté des Mineurs," by Mr. J. B. Marsaut, *Bulletin de la Société de l'Industrie Minérale*, 1883, vol. xii., page 321. "Miners' Safety-lamps: an Investigation," by Mr. J. B. Marsaut, *Transactions of the Midland Counties Institution of Engineers*, 1884, vol. xii., page 179. "The Marsaut Lamp," by Mr. M. Walton Brown, *Trans. N. E. Inst.*, 1885, vol. xxxiv., page 161.

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space he covered the more he reduced its safety. The soundness of this reasoning was confirmed by the Prussian Fire-damp Commissioners who carried it a point further, namely:—That any covering-up or obstruction, *a*, of the upper part of the gauze (Fig. 5, Plate XI.) also added to the possibility of the flame of an explosion passing from within the lamp to the surrounding atmosphere. They further proved that the doubling of the top of the gauze by a cap of gauze, *a* (Fig. 6, Plate XI.) or thin metal, *a* (Fig. 5, Plate XI.), also lessened the safety of the gauze-part. These experiments confirm Mr. Marsaut's results, for instance, where by placing a disc of gauze, *a*, in a Davy lamp a short distance below the top (Fig. 7, Plate XI.), he found that gas was easily ignited in a quiescent atmosphere in the annular space, *b*, thus formed. Mr. Marsaut also proved that if a second gauze, *a*, were placed round a Davy gauze, *b* (Fig. 8, Plate XI.), and in close contact with it near the top, thus creating an annular space round the gauze, the gas within this space was easily ignited by an explosion within the first gauze. These experiments demonstrated that the custom of placing a smoke-cap of gauze on the top of Davy and Clanny lamp-gauzes seriously reduced their safety; it likewise shewed that the safety of a gauze which from any cause had become smoked up or closed with dirt, was thereby seriously reduced; further they demonstrated that a single gauze was safer without a smoke-cap than with one; and that when using double gauzes, as in the Marsaut lamp, there must be a clear annular space between the two gauzes, *a* and *b*, and that the thickening caused by the joining of the gauze-disc, *c*, with the sides as in some makes of gauze (Fig. 9, Plate XI.), should not project far enough to touch the inside of the outer gauze, nor yet project upwards so as to come into contact with the top of the outer gauze. A glass-lamp, with one or more superposed gauzes, was more liable to pass the flame of an explosion within the lamp to the outer atmosphere, if a small flame was being used, and still more so if it was canted on one side.

Applying these deductions of Mr. Marsaut and the Prussian Fire-damp Commissioners, it is reasonable to assume, until the contrary is proved, that the Evan Thomas No. 7 safety-lamp (Fig. 10, Plate XI.), recommended by the Royal Commission

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on Accidents in Mines as having "given upon the whole the best results,"* would not safely withstand a series of tests in quiescent explosive mixtures of air and fire-damp; that neither the Davy nor the ordinary Clanny lamps ought to be fitted with smoke-gauzes; that the bonneted Jack Davy lamp (Fig. 13), so largely used for making examinations for fire-damp, is seriously reduced in safety when testing for gas if the cylindrical glass is pushed up to the top of the lamp, thus covering the upper part of the gauze; and if, in addition, it is both sooty and dirty and used in an inclined position, it becomes actually dangerous.

The cooling effect on a wire-gauze by an explosive current of low velocity is less than that of a high one, and consequently a fire-damp flame may pass through a gauze more readily in a low velocity than in a high one.

When fire-damp fills a lamp from the top it sets up more dangerous conditions than when it enters from below or horizontally, and many bonneted safety-lamps are so imperfectly shielded from descending or vertical currents, that it is possible for them to become filled with fire-damp, and to have the wick-flame crushed down and thus bring about an especially dangerous condition, as noticed by the Belgian Fire-damp Commission and Mr. Marsaut (Fig. 11, Plate XI.).†

Dust mixed with fire-damp, and forced on to a lamp by a fall of roof or otherwise, may become incandescent in the burning gas within the lamp, and passing through the gauze in this condition may ignite the surrounding atmosphere without the gauze becoming more than red hot.

In ordinary safety-lamps, the gas-and-air mixture continues to burn inside the gauze after the wick-flame is extinguished, and, therefore, they ought to have double gauzes as in the Marsaut lamp.

Applying the foregoing experimental and positive facts to the elucidation of the Elba and Clydach Vale explosions, it appeared in the opinion of the writer, reasonable to conclude that:—(1) They were caused by the failure of perfectly good safety-lamps of approved construction; (2) the failures were

* *Final Report of H.M. Commissioners appointed to inquire into Accidents in Mines*, 1886, page 118.

† An explosive mixture, ignited by an electric spark at the point, *a*, ordinarily occupied by the flame, passes the gauze at every ignition.

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due to the lamps becoming filled from the top with fire-damp, only slightly diluted with air, and accompanied by some coal-dust; (3) either explosion may have originated whilst an ordinary test for fire-damp was being made: (4) as other explosions had occurred in like manner, but had always been attributed to the ignition of gas after a fall of roof had first smashed a lamp and uncovered the wick-flame, the time had arrived when an enquiry should be made as to the dangerous influence of coal-dust on the stability of all types of bonneted safety-lamps; (5) no type or pattern of safety-lamp, which had not first been submitted to, and approved by the Home Office authorities, should be allowed in a coal-mine where safety-lamps were required; and lastly, (6) the recommendation of the Royal Commission on Accidents in Mines should be enforced, namely, (*a*) "it is most important that the merits of new inventions [relating to safety-lamps] should be properly ascertained"; (*b*) "it would be desirable for the Government to maintain an apparatus [for testing], such as we have used in our experiments, and to appoint some person to test and report to the Secretary of State on any [safety-]lamps which may be submitted to him" [for use in mines];* (*c*) "only those lamps should be used which are authorized from time to time by the Secretary of State"; and (*d*) "the use of ordinary Davy and Clanny lamps . . . . should be prohibited, unless they are enclosed in cases capable of effectually preventing the

FIG. 14.—LARGE BONNETED CLANNY SAFETY-LAMP.

* *Final Report of H.M. Commissioners appointed to inquire into Accidents in Mines*, 1886, page 88.

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gauze from being exposed to the full force of the current of air."*

It may be assumed, without any fear of exaggeration, that there is no legal limit to the dimensions of the gauze part of a safety-lamp, nor to that of the glass part, nor to the size or form of the bonnet, nor is it really necessary to prove that any new or old construction of safety-lamp is really safe before being taken into the workings of a colliery; and, therefore, so long as a safety-lamp is so constructed as to be carried against the velocity of air-current "ordinarily" prevailing in that part of the mine in which the lamps are for the time being in use, even though such current should be inflammable, the law is fully complied with.

Fig. 14 is the biggest lamp of the bonneted Clanny type ever seen by the writer, and its failure whilst in sound condition caused an explosion, in October, 1904, at the Birmingham gas-works, by which two men were killed and immense damage done to the purifying and other buildings. This lamp is a good illustration of the very wide difference there is between the dimensions adopted by Sir Humphrey Davy and those used in some cases at the present day, as the following approximate table shows:—

Description of Safety-lamp.	Contents of the Glass or Cannon Part. Cubic Inches.	Contents of the Gauze Part. Cubic Inches.	Total Contents exposed to an Internal Explosion Cubic Inches.
Evan-Thomas, No. 7 (Fig. 10, Plate XI.)	10·45	5·50	15·95
Bonneted Clanny (Fig. 12)	7·80	10·60	18·40
Bonneted Fireman's Davy (Fig. 13)	0·00	8·00	8·00
Large Bonneted Clanny (Fig. 14)	96·00	57·00	153·00
Scotch Gauze	0·00	86·50	86·50

The large bonneted Clanny lamp (Fig. 14) also differs from the bonneted Clanny lamp (Fig. 12), in having a supplementary air-supply to the wick-flame through two tubes, which are seen projecting above the oil-reservoir. These tubes are protected by a fixed disc of gauze placed between them and the air-admission holes in the side of the base of the lamp.

In conclusion, it is very important to note that a safety-lamp may be safe when carried against the current ordinarily prevailing in a certain part of a mine, even when it is inflammable.

* *Final Report of H.M. Commissioners appointed to inquire into Accidents in Mines*, 1886, page 118.

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and yet may not be able to withstand the rush of air, gas and dust caused by a fall of roof, such as is of common occurrence in collieries.

The PRESIDENT (Mr. H. Bramall) proposed a vote of thanks to Mr. Ashworth for his paper.

Mr. W. SAINT seconded the resolution, which was unanimously approved.

Mr. JOHN GERRARD (H.M. Inspector of Mines) said that he would first speak of that portion of the paper with which he entirely agreed, and which very strongly commended itself to him. He thought that one of the most important points was touched upon at the close of the paper, when Mr. Ashworth remarked upon the extraordinary fact that almost any lamp could be taken into a mine, however dangerous; this statement seemed strange at first sight. There was nothing really to fix or determine what was a safety-lamp; and that fact led him to express the hope that soon there would be an authorized establishment for the testing of lamps, to prove whether they were safe or dangerous, and not to wait until they had been tested in a mine by loss of life. It was exceedingly interesting to him (Mr. Gerrard) when visiting Belgium to see the admirable testing-station connected with the Belgian Government, under the supervision of two inspectors of mines, where a series of experiments were made with a number of lamps. If there were in this country some similar lamp-testing station, he was sure that it would be of very great advantage.

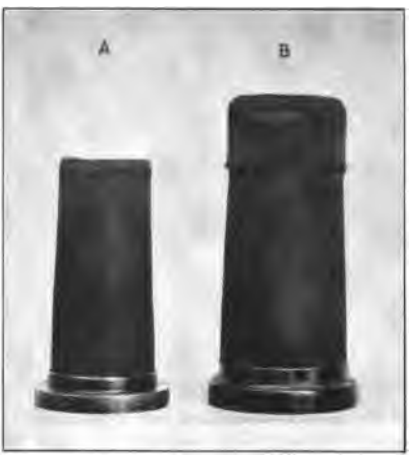

FIG. 15.—SAFETY-LAMP GAUZES. A: SHAKERLEY LAMP, B: SINGLE GAUZE AND CAP.

The next point of agreement that he had with the writer of the

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paper was associated with the introduction of lamps into Lancashire. He thought that up to recently there were a very large number of Marsaut lamps in use with proper double gauzes, and it had given him (Mr. Gerrard) some anxiety to notice that recently lamps were being introduced, into the collieries of Lancashire, with a single gauze, and a cap on the top similar to the cap (B, Fig. 15), which had been so strongly condemned by Mr. Ashworth. It was not only the single gauze with the small cap at the top to which he objected; the type of the gauze was not right. Fig. 16 was the lamp which unquestionably caused the Shakerley explosion; and, although it stood condemned as a type of lamp which could not be depended upon, it was this kind of lamp which was being extensively used in some of our most fiery mines. A (Fig. 15) is the gauze of the lamp shewn in Fig. 16.

FIG. 16.—BONNETED CLANNY SAFETY-LAMP: SHAKERLEY COLLIERY.

There were three points which should be very carefully considered in reference to these lamps:—(1) The fact that they had a single gauze. (2) They were of large internal capacity as compared with the old form of Clanny lamp, which had been so much criticized and had caused many explosions. He had himself investigated explosions that were held to be due to the use of that form of lamp. The diameter of the Shakerley lamp-gauze was $1\frac{1}{2}$ inches and the height $3\frac{3}{4}$ inches, and the diameter of the new lamp-gauze was 2 inches and the height 4 inches. (3) The cap was, probably, intended to be an additional

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safeguard, but. if he were right in his estimation of Mr. Ashworth's remarks, it stood condemned.

Referring to that part of the paper with which he (Mr. Gerrard) did not agree, in connection with his colleague, Mr. F. A. Gray, H.M. inspector of mines, who had made a most able report upon the Clydach Vale colliery explosion; he (Mr. Gerrard) said that Mr. Ashworth had dealt with the cause of this explosion, and there was some discrepancy between Mr. Ashworth's statements and the statements embodied in Mr. Gray's official report, and he submitted that Mr. Ashworth had not done Mr. Gray full justice. Mr. Gray thought that the cause of the explosion was the lamp used by David Enoch, and he condemned its use.

He (Mr. Gerrard) was glad that this question of safety-lamps had been raised, and he hoped that it would be seriously considered by the mining world. To his mind, the Shakerley lamp was better in form than the modern type, which was being largely used. After the Shakerley colliery explosion, this lamp (Fig. 16) was experimented upon to see whether, at a low velocity, flame would pass the gauze. It was true that they did not succeed in passing flame at a low velocity, but the lamp got into such a red-hot condition, that one could readily understand that a little disturbance of the air, and the raising of some dust, would lead to a disaster. The specific point upon which he desired Mr. Ashworth's opinion was as to the form of the gauze in the lamp put before the meeting. Another statement of Mr. Ashworth's wanted explanation, "the cooling effect on a wire-gauze by an explosive current of low velocity is less than that of a high one, and consequently a fire-damp flame may pass through a gauze more readily in a low velocity than in a high one."* If that statement implied that it is safer to jerk a lamp quickly out of gas, he (Mr. Gerrard) entirely dissented; the opposite had been proved again and again. The Special Rules required a lamp to be withdrawn slowly from gas.

Mr. Geo. H. Winstanley remarked that many modern so-called safety-lamps appeared to be made without knowledge or due regard of essential scientific principles, and many firms made lamps like the one exhibited by Mr. Gerrard. In the case of the English pattern of the Mueseler lamp, this was particu-

* *Trans. Inst. M. E.*, 1906, vol. xxx., page 515.

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larly evident; and, whilst in the original Belgian lamp the dimensions of the various parts were carefully laid down by the Government, the English copy, used in at least one extensive Lancashire colliery, was a Mueseler in name only, the makers having entirely lost sight of its essential features.

Mr. SYDNEY A. SMITH (Honorary Secretary) understood that Mr. Ashworth claimed that this particular lamp, in an atmosphere with a small percentage of gas, without dust, would not pass the flame through the gauze, but that under certain conditions, when dust was floating about, the particles of dust might become incandescent and then pass thraugh the gauze and ignite the explosive atmosphere at the outer side of the gauze. In other words, the incandescent particles of dust, passing through the gauze, would ignite the explosive atmosphere of a small percentage of gas and dust on the other side of the gauze. In his own view, it was hardly possible for those particles of incandescent dust to pass through the gauze at such a temperature as to fire the mixture outside, unless the gauze was at a temperature such that it would pass the flame entirely independent of the particles of incandescent dust, or itself fire the explosive mixture of air, gas and coal-dust.

The PRESIDENT (Mr. Henry Bramall) said that he had listened to Mr. Ashworth's paper with great interest, but when he heard the description of the finding of matches, pipes and cigarettes in fiery mines, he wondered whether the discipline was as strict as it might have been, apart from the question of the kind of lamp in use. The recommendation that each miner should have his own lamp struck him, too, as a little curious, as it had always been his own practice, and he thought that it was the general practice of other managers, in Lancashire at all events, for every miner to have his own lamp and to be held responsible for it. He considered this to be very necessary. Mr. Ashworth had done good service in recalling attention to the experiments of Mr. J. B. Marsaut on the forms of safety-lamp gauzes, as these experiments were not so familiarly known as they ought to be. The suggestion was ingenious that coal-dust or other dust was fine enough to be carried through a red-hot gauze into a lamp, and, having therein become incandescent, to pass through the gauze out of the lamp and fire the gas outside; but it seemed to him that, if a lamp were made red-hot by a low-velocity current con-

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taining fire-damp, any coal-dust mixed with such current would be immediately inflamed on contact with the red-hot gauze, and so might cause an explosion. Mr. John Gerrard had called attention to the introduction into Lancashire mines of a lamp which was giving him anxiety, as he did not consider that it was safe. From what he could see of the lamp, his (Mr. Bramall's) opinion coincided with that of Mr. Gerrard, and he certainly would not be prepared to adopt it, or even try it, without satisfactory tests being applied. He entirely agreed with Mr. Gerrard's suggestion that safety-lamps ought to be, in some manner authoritatively tested, but he was scarcely prepared to go so far as to suggest that the Government should have power to order the use of any special type of lamp. He certainly thought that the Government ought to establish a lamp-testing station or stations, which might be placed under the supervision of a committee composed, say, of some of the inspectors of mines and some of the leading mining engineers. Lamps should be tested as to their safety exactly as explosives are now tested, and the Government might issue a list of authorized or "permitted" safety-lamps. What had been done hitherto had been chiefly left to private enterprize, but if any pressure could be brought to bear on the Government to induce it to establish lamp-testing stations it would be very beneficial. They might issue detailed specifications of the dimensions of the best types of lamps and particulars of their construction describing the forms and sizes which were safe. Such details would meet the point to which Mr. Winstanley had called attention, and so unscientific lamp-makers would be able to make lamps in accordance with those instructions and that would be a distinct gain. It would appear, at present, that it was quite possible for a manufacturer to make and put on the market almost any kind of lamp and call it a safety-lamp, and even to patent it, although it might be defective and a dangerous lamp to use; and, as Mr. Gerrard had pointed out, colliery owners might introduce these faulty or unsafe lamps into pits. He thought, however, that if the lamps which were coming into use were dangerous, it was time that the Government took some action. His impression was that an inspector of mines could object to any appliance found in a pit, if in his judgment it was unsafe; and, if the mine-owner persisted in its use, the matter would be referred to arbitration. The inspector of mines might not have the power actually to forbid the use of any lamp

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which he did not consider safe; but no doubt a recommendation from him would be seriously considered and he suggested that the inspectors of mines ought, in the first instance, to take that course. If, thereafter, an owner was contumacious, he thought that the inspector of mines would be justified in taking stronger measures. This was a question of very serious moment, and action ought not to be deferred until there was an explosion and men were killed.

Mr. JAMES ASHWORTH, replying to the discussion, again expressed his agreement with the suggestion made by the Royal Commission on Accidents in Mines that the Government should establish a testing station for safety-lamps; and the cost would be trifling in comparison with the importance of the issues at stake. His object in writing the paper was to call public attention to certain important matters which had not received due consideration. He thought it unfair to condemn the bonneted Clanny lamp used at Clydach Vale colliery before the Davy lamp used by D. Enoch had been found and examined; and the condemnation seemed to him to have no sound basis. Mr. F. A. Gray said that the lamp was found under some debris; while he (Mr. Ashworth) stated that he had heard that parts were found in three separate places and he, therefore, thought that the condemnation was premature.

The coal-dust was so small that it could go into and out of the gauze, and when making tests with mixtures of air, gas and coal-dust, it was not necessary for the gauze to become very hot to cause a lamp to fail; it required only a small amount of coal-dust to carry the flame very quickly through the gauze. He did not know why the Royal Commission on Explosions from Coal-dust in Mines did not make experiments on safety-lamps with coal-dust, unless they were debarred by the cost, or thought that it was an unnecessary investigation.

The Belgian authorities had settled that a Mueseler safety-lamp chimney of certain dimensions was the safest form, but it had since been proved that the English construction of chimney was better than the Belgian form. Mr. J. B. Marsaut had proved that the explosion-flame did not pass up the chimney, but through the gauze at its base. He (Mr. Ashworth) had no hesitation in saying that the English form of Mueseler chimney was safer than the Belgian form in a fiery place.

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PART VIII. VOL. XXIX.

TRANSACTIONS

OF THE

MANCHESTER GEOLOGICAL & MINING SOCIETY.

EDITED BY

THE HONORARY SECRETARY.

SESSION 1905-1906.

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OCT 1 '06

MANCHESTER GEOLOGICAL AND MINING SOCIETY.

ORDINARY MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
FEBRUARY 13TH, 1906.

MR. HENRY BRAMALL, PRESIDENT, IN THE CHAIR.

Mr. P. BARRETT COULSTON read the following paper on "The Use of Electricity in Collieries":—

THE USE OF ELECTRICITY IN COLLIERIES.

BY P. BARRETT COULSTON.

In view of the number of papers which have been written within the last few months on this subject, and the feeling which is apparently taking root in the minds of colliery engineers that electricity can only be used successfully for a small number of operations throughout mines, it has occurred to the writer that it would be interesting to discuss some of these items from an engineering standpoint: having specially in view the advantages to be obtained by the application of electricity on the one hand, and the difficulties of applying electricity to compete with the present methods on the other hand.

Winding.—Winding, at the present moment, is the greatest obstacle that electrical engineers have to overcome, for there can be no doubt, in mines of a large capacity, that the cost of an electrical winding-gear is considerably higher than that of a mechanical winding-gear; and the general opinion on this subject expressed by the writers of recent papers, before mentioned, is that it is almost impossible for any system of electrical winding to supersede the present mechanical system. The writer believes that

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this is a totally erroneous and pessimistic opinion (from the point of view of an electrical engineer) and is very largely due to the fact that electrical engineers have not yet thoroughly laid themselves out to cope with this question. Especially on the Continent, elaborate systems of electrical winding have been installed, costing large amounts of money in excess of that required for a mechanical system, and the results obtained have not been such as to warrant a widespread demand for this type of winding-gear. Probably, the majority of the members are aware that the general system adopted consists of a large number of units, starting with an engine driving a generator, which in turn drives a motor-generator, and this again in turn drives the winding-motor or motors. The engine, in all cases, has been of the slow-speed type, consequently the first cost has been almost equal to the cost of the engine for mechanical winding. There are, however, several systems, now under consideration, tending greatly to decrease the first cost of the electrical plant, such as the Rateau, Georgi, continuous winding and Beschnedorff.

Rateau System.—This system is a combination of a mechanical and an electrical system. The engine is used for driving the winding-gear, and the exhaust-steam from the engine is carried into a receiver or chamber, generally consisting of an old boiler. This low-pressure steam is then used for driving a combined turbine and electrical generator, which supplies power to different machines underground, and may be used for lighting the colliery. This system has been adopted in one or two installations, and although no reliable figures have been published as to its working, yet the general opinion of the engineers responsible for the same is one of satisfaction.*

Georgi System.—In this system, a high-speed engine or turbine is used to drive a heavy flywheel; also a separately excited winding-motor and a speed-controller, as in the Ilgner system.†

* "The Utilization of Exhaust-steam by the Combined Application of Steam-accumulators and Condensing Turbines," by Prof. A. Rateau, *Trans. Inst. M.E.*, 1902, vol. xxiv., page 322.

† "Notes and Considerations on Systems having Work of an Intermittent and Irregular Character to Perform: Methods of Load-compensation," by Mr. Maurice Georgi, *Trans. Inst. M. E.*, 1904, vol. xxviii., page 89.

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Continuous-winding System.—This system of winding is being strongly advocated in the United States, and the theory, although no doubt of a somewhat bold nature, should not offer any insuperable difficulty to engineers. The idea is to run the cages continuously, without being stopped at all for loading or unloading, the corves being run in and out as the cages pass the stages. It is, of course, obvious that either the speed of winding will have to be greatly reduced to allow of this being done, or else some system must be arranged by which the cages could be, as it were, shunted off the ropes and run at a much slower speed. This system has been used, for a considerable period of years, in connection with mechanical lifts, and has given every satisfaction. Owing to the fact that in winding-machinery, running at a uniform speed in one direction, the load would practically be that of a straight-line curve, which would allow of much smaller and lighter machinery being installed.

Beschnedorff System.—This system, which has been installed at a mine in Southern Russia, consists of an engine driving a direct-current dynamo, which in turn supplies current to a motor through a battery of accumulators. Very considerable difficulty has, however, been experienced, owing to the fact that two batteries are used in parallel, a large number of the plates are found to buckle very quickly, and the upkeep of this battery is very costly. Electrical accumulators, however, are now being made to stand very heavy rapid charging and discharging, and, no doubt, the difficulties, accompanying this system, would be largely minimized in an installation of the present day.

Another system, with which some extremely satisfactory results have been obtained, is that of a generator of the alternating-current type, driven by a turbine supplying current to a slip-ring motor of a high-power factor, driving the winding-gear; but, instead of the ropes being balanced, the tail-rope is much heavier than the head-rope, in fact, equal in weight to the combined weights of the head-rope and of the coal. Owing to this arrangement, when starting to hoist, the engine has only to overcome the inertia of the moving parts to produce acceleration, the load increases as the wind continues; and, when the current is switched off, the unbalanced weights of the rope and

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of the coal act as retarding forces, bringing the cages to rest with a minimum of braking effort. A great advantage is obtained by this method of overbalancing, the maximum power required being considerably reduced; or, looked at in another light, with the same power expended, considerable increase in the rate of acceleration may be obtained, without any tendency for the gear to run away at the end of the wind.

Mr. W. C. Mountain, in his paper recently read before the Institution of Electrical Engineers,* showed, by his calculations, that the costs of winding 2,000 tons of coal in a day of 8 hours would be: (1) by an electrical system, 3s. without interest and depreciation, and 12s. 5d. with interest and depreciation per 100 tons; and (2) with a mechanical system, 3s. 5¼d. without interest and depreciation, and 7s. 2½d. with interest and depreciation per 100 tons. From these figures it will be seen that whilst there is an undoubted saving in the actual working costs, the interest on the first cost militates greatly against the electrical drive. Mr. Mountain's figures were made up as follows:—(1) Electrical system: winding-plant, £14,200; generating-plant, £5,500; and boilers, £3,600. (2) Mechanical system: engine, £6,500; and boilers, £3,000.

The author is of opinion, however, that the costs given by Mr. Mountain are distinctly high, and he feels satisfied that, even when using the same system, an electrical plant could be installed at a considerably less first cost. It should, however, be noted that these comparisons are simply taken on a plant for one shaft only, and where (as at so many collieries) there are several shafts, the electrical drive would, at once, begin to compare favourably as regards first cost with the mechanical system, owing to the possibility of having one central generating-station and boilers, instead of having a number of isolated batteries. It should, also, be noted that when the fact is taken into consideration that the electric current may be supplied to the winding-plant and also to machines underground, instead of erecting a separate plant, this discrepancy in the costs of the mechanical and the electrical systems is again greatly reduced. Some inter-

* "Electric Winding in Main Shafts considered Practically and Commercially," by Mr. W. C. Mountain, *Journal of the Institution of Electrical Engineers*, 1906, vol. xxxvi., page 499.

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esting figures, recently published, seem to demonstrate that, if the electrical system were adopted for the whole of the operations on the surface and underground, the cost of the machinery would be only slightly higher than that required for the mechanical system, and that the actual working costs were reduced from 10 to 30 per cent.

There is also another argument for the use of electricity, but, in the author's opinion, it has been almost worked to death by the advocates of the mechanical system, and that is, the question of the extra labour entailed in superintending the running of electrical machinery. This, however, actual experience has proved, even with the systems of winding now in use, to cost no more for the electrical than for the mechanical. In the future, when, as the writer firmly believes, the turbine will be used almost universally for providing the motive power of the generating-plant, both the wages and upkeep will be considerably less than at present. There are no reciprocating parts, whatsoever, in the turbine, and there is only wear on the bearings, due to the fact that the steam forms a bearing for the whole length of the turbine.

Much has been made and probably will be made by the advocates of the mechanical system of the contention that, to obtain steam results to compare favourably with the mechanical system, superheated steam must be used, and that it has an extremely deleterious effect upon the turbine-blades. There are, however, many turbines, each yielding over 1,000 horsepower, in operation at the present moment, that have been running for very long periods with steam superheated to as much as 300° Fahr.; and the reports, on the examination of these turbines, show that the wear on the blades has been an absolutely negligible quantity. It should, moreover, be noted that, with an electrical installation, the question of the site for the engine-house can be decided without considering, for one moment, the question of the position of the mine-shaft; and this is often a question demanding a considerable amount of attention, having especially in view the question of water-supply.

There is also another point, dealing with the question of first cost of an electrical winding-plant, and that is, the possibility of taking a supply from the large power-companies, now start-

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ing operations in this country. Some of the prices, for electric current, which have been quoted by these companies are extremely low; and as, for the purpose of making dividends, it is necessary that the machinery should be kept running constantly with as near a maximum load-factor as possible, it is more than probable that any large colliery, guaranteeing to take power from one of these companies, would be offered very favourable terms. This is being done, at the present moment, in staple-pits, and the costs of running are found to be extremely low, and to compare very favourably with the mechanical system.

Haulage.—In the author's opinion, the electrical system is undoubtedly the most economical and efficient for haulage; and, where main-and-tail haulage is employed, the load on the motor, in actual practice, has been shown to be so regular that it is a common occurrence to see the ammeter, connected to the motor, running steady within 5 per cent. of the normal load.

Coal-cutters.—This subject is the one, which up to the present time, has received the greatest amount of attention from both manufacturers, and mine-owners and managers, and the almost phenomenal rapidity with which these machines have replaced manual labour is an undoubted proof of their success. The power applied to the driving of coal-cutters may be roughly classified under two heads, namely, compressed air and electricity, the latter type being undoubtedly the most economical.

Coal-cutters may be divided into three classes, namely, disc, chain and bar cutters. The design of these machines has received the most careful attention from many engineering firms, during the past few years, with the result that the later machines, now placed on the market, are all of a highly efficient character, combining with this desirable factor that of extreme simplicity, and almost complete immunity from breakdowns. When these machines were first produced, the general opinion was held that, without a long and straight coal-face, it would be impossible to use them economically; experience, however, has proved that almost any coal-face that can be worked by hand, can be worked by means of the coal-cutter: but there is one point on which the author would lay special stress, namely, that different

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seams must be considered on their own merits. It is obviously unfair to consider that a coal-cutter which will do satisfactory work in one seam, should without adjustment give the same result in a seam of a different nature.

A point worthy of consideration, with the coal-cutter, is the way in which it has superseded the pick for holing; and it should, also, be noted that the line of cut of a coal-cutter depends only on the direction in which the rails are laid. The opinion has been expressed by many colliery managers that whilst the coal-cutter is undoubtedly a phenomenal improvement over hand-labour, its best results could only be obtained in a cut not less than 4½ feet under: this being the minimum cut that allows of timber being set under the new roof, and still leaves room for the cutter to pass between the timbers and the coal-face; but the newer designs of coal-cutters, especially the Birtley-Falcon, have been designed to work in a much smaller cut. It is also felt that, if the cutting were done at the floor-level, better results would be obtained. It has, however, been found that equally good results could be obtained when cutting in any dirt-band that might exist in the seam of coal.

Before describing a few of the prominent types of coal-cutters, some of the definite results, which have been obtained in actual practice, may be summarized as follows: (1) An increased output per man employed; (2) coal can be economically worked that, previously, had been unworkable by hand-labour; (3) more systematic working; (4) better round coal; (5) greater area exposed in the same time; and (6) the premium per ton, for risk of life, is reduced by one-third.

The author adds the following notes respecting the preceding results:—(1) The increased output, statistics of which have been kindly furnished to the author by the managers of several collieries, is at least four times the amount obtained by hand-labour.

(2) Actual practice has proved that, in pits, where as much as 1s. per ton extra had been, previously, paid to the collier for working hard coal, the work could be done by the machine, without any extra cost, for power or attention, over and above what it cost for working ordinary soft coal.

(3) In addition to more systematic working may be mentioned

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a steadier output, due to the fact that the cutter will satisfactorily deal with either soft or hard cutting (due to any pyritic material) by suitable speed-regulation. Consequently, the sole requirements for the man in charge of the machine are to keep the cutter constantly forging ahead, and to keep his filler and drawer up to their work, so as to prevent any accumulation of coal.

(4) The quality of the coal is emphatically changed by the use of the coal-cutter, this increase in quality depending entirely on the nature of coal worked; but the results, taken from several mines, shew an increase, on an average, of about 17½ per cent. In connection with this subject, it may be interesting to note one great difficulty which was met in the early days of the cutter, that it showed an almost unnatural preference for cutting into any band of dirt on the floor that it came across, thus reducing the value of the slack to almost *nil*. This dfficulty, however, has been completely overcome in the later types of cutters, and the quality of the slack is quite equal in value to that of hand-worked coal.

(5) The area of ground exposed is, of course, in proportion to the number of tons filled per foot of face.

(6) The figure stated, namely, a reduction of one-third, is an extremely conservative one, and it is based on the fact that any coal-cutter will increase the amount of coal obtained to double that obtained by hand, and, further, that the labour will be reduced by at least one-third. Some of the later results, however, show that, whilst the labour would be reduced by over 50 per cent., the increase in the amount of coal obtained is over four-fold, consequently reducing the premium by this greater amount.

The Birtley-Falcon electrical coal-cutter, designed to withstand rough usage on heavy work, and operated by one man and a lad, consists of a frame carrying the motors, the haulage-gear and the controller, everything being thus self-contained. The disc can be situated either in the centre of the machine, or midway between the motors; it will cut the coal with equal facility in either a backward or a forward direction along the coal-face; and it is practically free from any side-thrust. All intermediate shafts are dispensed with by the use of helical gearing, the wearing parts of which are enclosed in an oil-bath,

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thus providing efficient lubrication; and the whole of the gear is protected by a dust-and-gas-tight case. The feed-mechanism is of the variable type, permitting variation of the rate of cutting, from the slowest up to full speed, without a stoppage of the machine; thus preventing, with ordinary care of the operator, any blowing of fuses; and the machine is, further, easy of regulation, when cutting in different qualities of coal. The machine, designed for running on either skids or rollers, is fitted with a face-wheel, which is adjusted to suit the variation of the coal-face, thus entirely preventing any wedging of the machine, which might cause damage to the timbering. For the purpose of crossing bord-rooms and gateways, a device is fitted, by which the pinion, driving the disc, can be detached, allowing the machine to haul itself along whilst the disc remains stationary.

Pumping.—Probably in no other application of engineering is the necessity of careful consideration of greater importance than that occasioned by pumping-plant at collieries. It is on record that, at some mines, the weight of water raised per annum is considerably in excess of the quantity of coal raised in the same time; and pumps of sufficient capacity must be installed to ensure that this water be kept down, or otherwise the mines would be flooded out. Electrical driving has proved, on account of its flexibility, to be considerably in advance of any other system. In many cases, pumps are mounted on a truck and moved down the roadways as the water is pumped out of the mines; and, further, an electrically-driven pump may often be found in an out-of-the-way corner, left without attention, except for being overhauled occasionally.

The sizes of pumps vary entirely with the requirements of the mines in which they have to be installed. In some mines, a very small pump is required to deal with, say, 20 gallons per minute; in others, pumps of much larger capacity are used; and in one case, a centrifugal pump, driven electrically, is raising 1,700 gallons of water per minute, against a head of 1,800 feet. Roughly speaking, the pumps installed vary in units from 500 to 600 horsepower; and, in many electrically-equipped mines, the generating-station, during working hours, is supplying power for the output of coal, and at night for pumping, thus materially reducing the capital-expenditure. The types of pumps most

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commonly in use are (1) of the three-throw type, driven through suitable gearing by a motor, and (2) of the centifrugal type.

Fans.—Electrically-driven fans are now so common, that a description is quite unnecessary. The powers mostly in use range from 20 to 300 horsepower, and the load is very steady.

Screens.—Here again a steady load is found for the motor: the average size of motor required varying from 10 to 50 horsepower.

Lighting.—Electricity is now generally used for lighting collieries, the usual practice being to instal a low-voltage direct-current set, to deal with the exciting of the alternators if such are installed for the power-plant, and the generator is, also, designed of sufficient size to deal with the lighting.

Considerable difficulty was experienced, in the early days, in obtaining cables with a good insulation-resistance, due to the somewhat abnormal conditions under which these cables were placed at the surface. This difficulty, however, has now been quite overcome, and with suitably-chosen cables there is no reason why the insulation-resistance of a colliery-lighting installation should not be equal to that of an installation in any public building. It is very seldom that faults are found in the cables used for underground lighting, even in a damp mine, and, as before stated, the sole trouble experienced has been on the surface. Where electrical power is used in the mine, it is of course unnecessary to run the lighting-mains to the face, where working operations are in progress, as a batch of lamps can always be connected across the power-mains.

Electricity is also used for lighting miners' lamps, and it is found that this method saves a large quantity of oil, where the lamps have been sealed and examined.

Shot-firing.—Electricity is used for igniting the fuses for shot-firing, the two systems generally adopted being either the high or low tension. In the case of shot-firing for shaft-sinking, the current is frequently taken from the lighting-mains: and with the low-tension system, either a battery or a hand magneto-generator is used.

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Signals.—Telephones and electric bells are now fitted in a large number of collieries for purposes of inter-communication and signalling. The voltage allowed in fiery mines, by the Home Office Rules and Regulations for the Use of Electricity in Mines, for the use of signalling apparatus, must not exceed 15 volts; and this means that cables of a large sectional area must be installed, to prevent undue drop in travel. Practice has proved, however, that the (sometimes rather heavy) first cost of the installation due to this fact is quite outweighed by the increase in efficiency of the signalling-arrangements.

System of Supply.—A considerable diversity of opinion is still held as to whether direct or alternating current is the more satisfactory system to be used. The direct-current system has been more generally adopted up to the present time, and, generally speaking, is giving eminently satisfactory results, very little trouble being experienced in breaking the circuit in a switch-box. This can, of course, be overcome by having the switches under the control of the attendant at the pit-mouth, but this method is expensive. In the author's opinion, the alternating-current system is most suitable, and most likely to be adopted for future installations. On account of the fact that squirrel-cage motors, with a high-power factor, can be used for any operation throughout the mine, sparking troubles are at once eliminated, and oil-switches can be installed; and this alone, in the author's opinion, is almost sufficient to warrant preference being given to the alternating-current system.

Contrary to the general idea, it has been found that high voltage does not make any marked saving, and this is due to the fact that the average run from the machine to the distribution-board is well within the distance that allows of running economically with a low pressure.

Generating-machinery.—In the design of the generating-station for a colliery, great attention must be paid to the question of the load-factor of the machinery to be installed. It is impossible to make any general rules for this subject, and each individual case must be considered on its own requirements. Some collieries, where the load maintains a steady average over long hours and where the pumping is done at night, show an

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extremely high and satisfactory load-factor. Others, where the working is intermittent, have an extremely variable load and low-load factor. It should, however, be pointed out that, in the latter case, a considerable improvement in the load can be, and in many cases has been, reached by drawing up a rough time-table for the use of the machines at the mine. Possibly, owing to the fact that the coal necessary for generating steam is immediately at hand little attention seems, in the past, to have been paid to economy in steam-consumption; but, as larger units are being installed, this item is receiving the attention that it merits.

For the generation of the current, the general practice, advocated by the author, favours the use of reciprocating engines, working at a high steam-pressure, driving alternators for sets up to the capacity of 500 kilowatts; and, above this, the use of steam-turbines, also direct-coupled to alternators.

The switchboard and auxiliary plant can be placed in the enginehouse; and the cost for attendance and maintenance of a suitably designed and equipped station is found to be very low. Many cases may be cited, where, allowing 20 per cent. for spares, 5 per cent. for depreciation, and 5 per cent. for interest on capital, the generation of electricity costs below 0·38d. per unit.

Gas-engines.—One point that has often been brought to the author's notice is the suitability of a gas-plant, comprizing:—Gas-producers, and large power-engines for driving electric generators. In the author's opinion, however, the time has not yet arrived at which gas-engines have reached such cheapness in first cost, and reliability in running continuously at full load for long periods, as to enable them to compete with reciprocating steam-engines or turbines.

Special Rules.—A special committee appointed by the Home Secretary sat in 1902 and 1903 on the question of the use of electricity in mines, and their report was issued in 1904; and, in the early part of this year, the set of rules, now in force in this country, was issued by the Home Secretary. Generally speaking, these rules are fair in their requirements, with the possible exception of the rule relating to the suspension of cables, which distinctly states that leather or other flexible material must be used for suspending cables underground.

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Apart from the fact that a large number of collieries in this country, previous to the publication of these rules, had installed many miles of cable, which, generally speaking, are fastened by cleats, very often in almost inaccessible places (and to alter the method of suspension to meet the new requirement would entail considerable expense); there is a general consensus of opinion amongst colliery engineers that cables suspended in accordance with the new regulations would be more liable to damage of insulation than if rigidly suspended.

Maintenance of Plant.—It was the experience of the pioneers of electrical driving that miners looked with great distrust upon any machinery, to which the name "electrical" was attached. This unreasoning prejudice has been largely overcome, the author's experience being that the average collier takes electrical plant quite as a matter of course.

In the early machines, great difficulty was experienced with the bearings, owing to coal-dust getting into them, but, with machines of present-day design, a minimum of care and attention is required; and the author knows of several motors which have been running practically day and night in a colliery for three years, without any attention further than regular lubrication.

No difficulty is experienced in training men, who have been previously employed in charge of steam-plant on the surface, to take over electrical plant, and these men themselves admit that their duties are considerably lightened with electrical plant.

The PRESIDENT (Mr. H. Bramall) moved a vote of thanks to Mr. Coulston for his paper.

Mr. P. C. POPE seconded the resolution, which was unanimously passed.

Mr. GERALD H. J. HOOGHWINKEL wrote that he wished to refute Mr. W. C. Mountain's figures on electric winding: they were absolutely wrong, for the actual cost per 100 tons at the Zollern II. colliery, including interest and depreciation of plant in the power-station, was 7s., when working at only half-load.

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Mr. PHILIP C. POPE said that Mr. Coulston mentioned first of all the question of winding, and drew attention to the Rateau system, by which the exhaust-steam from the winding-engine was put into a receiver or chamber, generally consisting of an old boiler, and this low-pressure steam was then used for driving a combined turbine and electrical generator to provide power for every purpose about the colliery. That system might be satisfactory where the winding was perfectly regular, and where there was plenty of storage-capacity for the exhaust-steam; but, in shallow pits, where the winds were of short duration and the time-interval between the winds was rather considerable, he questioned whether it would be very satisfactory. The Georgi system was like the Rateau system and quite as costly. In fact, whatever the system, it was rather costly to put down a special generating plant. Mr. W. C. Mountain in his paper* mentioned various costs and Mr. G. H. J. Hooghwinkel had controverted one of them; but Mr. Mountain, did not, in his paper, mention what he (Mr. Pope) believed was the last system of winding that had been brought out, and was much more simple in its application and more reliable in its working than any of the systems mentioned in Mr. Coulston's paper. Unfortunately, he was not permitted to go into the details of this latest scheme, but when it was made public he would have pleasure in giving the members information about it. He had only to say now that the capital-outlay under the new scheme would be less than under any of those mentioned in the paper, and should there be a breakdown in any of the balancing apparatus, it did not affect the possibility of winding by the main winding-motors. Of course he always spoke from a biassed point of view, for it was his business to supply power to people who would take it; but, according to Mr. W. C. Mountain's figures, given in Mr. Coulston's paper, the largest item of cost was interest and depreciation in respect of the capital-outlay, and a large portion of that was due to the generating plant. That item was, however, entirely eliminated in the case of the collieries taking current from power-companies, and they had the additional advantage of having a duplicate-supply in the event of a breakdown, which they did not necessarily possess in the case of their own generating plant. That im-

* "Electric Winding in Main Shafts considered Practically and Commercially," by Mr. W. C. Mountain, *Journal of the Institution of Electrical Engineers*, 1906, vol. xxxvi., page 499.

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portant point should be taken into account in settling whether to put down a plant of one's own or not. He (Mr. Pope) thought that all the power-companies gave a duplicate supply to large consumers, that was to say, two mains were carried to the colliery, each one of which was capable of taking the full load direct from the power-house independent of the other. The load-factor, mentioned by Mr. Coulston, was, of course, a most important matter, whether they were putting down a generator-plant of their own or getting a supply of power from an outside source. The power-companies were always willing to quote lower rates when a continuous load was required. Mr. Coulston, in his estimate of the cost of producing current at a colliery, allowed 20 per cent. for spares. He presumed that Mr. Coulston meant 20 per cent. additional capital; but the proportion to be allowed depended on the size of the generating plant, and under some circumstances 20 per cent. would be a small allowance.

Mr. George G. L. Preece said that the Rateau system had been installed at a colliery in the Midlands, and the manager who had installed the system had expressed a great deal of satisfaction in regard to its working. Mr. Mountain was an electrical engineer and would certainly have not gone deliberately out of his way to quote excessive figures. He agreed with Mr. Mountain that much harm had been done to electrical industries at collieries by the wild statements that had been spread abroad by too zealous advocates of electric winding. There was this, however, to be said that Mr. Mountain did not take enough notice of the fact that the capital cost of installing winding-plant would be considerably reduced, proportionately, in cases where a group of pits within a short radius took current from a central power-station. He was rather surprised to hear Mr. Coulston's remarks about the difficulty of obtaining good insulation-resistance on the surface, and that there were very few faults underground. He thought that colliery managers would rather like to find that such was the case, his own opinion being that the conditions underground were more severe than on the surface and needed better insulation. With regard to the Special Rules forbidding the cleating of cables underground, he did not see how a definite rule could be laid down. In some places, however, the cables could be cleated up at the side or overhead; in many places, they would be suspended, and the general consensus of opinion was

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that the latter method was more usually adopted. The Special Rules, moreover, do not absolutely forbid cleating, and the prohibition certainly was not intended to be binding. In any event, the Special Rules were not retrospective and did not interfere with cables fixed before the rules were adopted, except in so far as H.M. inspector of mines must approve of the method.

Mr. JOHN GERRARD (H.M. Inspector of Mines) said that he preferred to hear the experience of those who had used electricity for power-purposes. If he did speak, it would be to urge electrical experts to state the results of the application of electricity. We had heard again and again that electricity was applicable, and surely the time had arrived when figures could be given. The figures should be something more than the results of experiments over a brief period when everything was in order; they should cover a period to include breakdowns, in order that it might be known where the weaknesses were. Steam power-plant and compressed-air power-plant were liable to breakdowns, and people wanted to know what were the liabilities of electrical power-plant. It was said how essential it was to have first-rate workmanship; cheapness in electrical power was by no means economical; well, in his opinion, as electricity had been used for some time now in various ways for mining purposes, they would like to know the results.

Mr. T. H. WORDSWORTH said that the new winding-engine erected last summer at the New Moss colliery, with two cylinders, 36 inches in diameter with a stroke of 72 inches, was winding from a depth of 2,268 feet. Steam was supplied at a pressure of 120 pounds per square inch from two boilers, 30 feet long and 9 feet in diameter. Slack, passed through $\frac{3}{16}$ inch square mesh, was used for these boilers, and the consumption was 50 tons per week for an output of 3,350 tons, or a cost of 0·8d. per ton with the engines working about one-third of their time. Before putting down the new engine, the owners fully considered the question of winding by electricity, but the difference in the first cost was so great that, even if electricity were as economical as was suggested, the saving in coal would not have paid the interest and the depreciation on the extra outlay. It was intended to make full tests on this winding-engine within the next few months, and he hoped to be able to communicate the results to the members.

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Mr. Coulston stated in his paper that the output obtained by the use of coal-cutters was "at least four times the amount obtained by hand-labour," and he would like to know where such good results were being obtained. He agreed with Mr. Gerrard that although many papers had dealt generally with this subject, it was very difficult to get hold of figures for purposes of comparison. He had recently been endeavouring to compare electricity with compressed air, but he had found the greatest difficulty in obtaining reliable figures. In his experience, the starting-switches for haulage-motors constituted the weak spot. The figures given in support of electricity were usually based on plant working on the surface with a good load-factor, whereas the members required that motors working underground should be compared with up-to-date compressed-air machinery, as many of the old compressors were working with uneconomical steam-engines.

Mr. Charles Pilkington did not think that they could get the figures about the use of electricity underground at all easily. One had to consider not only what it cost to produce power, but the effect of a break-down; and absolute reliability was essential to success in coal-getting. At least a year's working should be taken before any reliable figures could be obtained as to the cost of underground working. He did not believe that any mine produced four times as much coal by coal-cutters as could be got by hand-labour. The machine was better than hand-labour in dealing with some sorts of coal, but it was at a disadvantage when dealing with other sorts. If the coal was hard, the machine was preferable, but when the coal became soft, the machine was removed because the coal could be got more cheaply by hand-labour.

Mr. H. T. Wilkinson said that it seemed particularly unfortunate that Mr. Mountain should read a paper, as he did, giving the impression that he had said the last word on electric winding in collieries. It must be remembered that his figures were taken from a plant constructed about five years ago, and necessarily designed some years before that. It was only natural to expect that such machinery, opening out a new field as it did, should have developed very considerably in the past five years. If the figures Mr. Mountain gave were analysed, it would be seen that before electric winding could compete with steam it would be necessary to halve the interest and depreciation on the former;

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that was to say, the capital-cost of the electric winding-gear must be reduced by one half before it could compete with steam-winding, and he understood that the scheme of which Mr. Pope spoke did that. It was, therefore, safe to say that Mr. Mountain had not said the last word on electric winding.

Mr. CHARLES PILKINGTON wished it to be known that he was not opposed to the use of electricity, his previous words having reference only to coal-cutting by electricity.

The PRESIDENT (Mr. Henry Bramall) regretted that he could not throw any light upon the subject, for he had not had any practical experience in the use of electricity for power-transmission. His experience had been chiefly connected with the use of compressed air, and he had not yet seen anything to induce him to exchange this for electricity. He entirely agreed with Mr. Gerrard in thinking that the members had read quite sufficient papers pointing out generally that electricity might be used in mines for certain purposes. He thought that these papers were rather more like newspaper-articles than papers to be read before a scientific society such as this. At the same time, the members were indebted to gentlemen for bringing the subject of electricity before them, but if they were to discuss its various applications thoroughly, they would have to consider such applications in separate detail, as the points raised were so many. They were all agreed that electricity could be applied for all the purposes specified in Mr. Coulston's paper, but they wanted to know what were the results. If any of the members were contemplating the erection of a new plant they wanted to erect that which would be the safest and the most profitable. It was important for them to know the cost and the advantages to be obtained from this or that system, and if the members could have some more specialized and practical papers giving that information, he thought it very desirable that they should have them, not only in regard to electrical winding but to every application of electricity. The question was raised as to the advantage to be gained by the use of electrical coal-cutters, but members had not been furnished with any detailed information such as would enable them to compare electrical coal-cutting with the use of compressed air for coal-cutting. With regard to the question of cost, although he would be sorry to see anything brought before the members that could be construed into an advertizement

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for any particular plant or apparatus that the author was interested in making or selling, at the same time on such a question as this, who were so competent to give them information as the people who were in the business and had made a special study of it? They, as colliery managers, had not had the opportunity of studying every point, and he thought that it would scarcely be considered advertizing if the experts in one branch of science or another gave them detailed figures (from actual results) as to the cost and advantage of this or that system. As to the cost of electrical winding, an estimate had been given by Mr. Mountain in which the price of fuel was put, if he remembered rightly, at 3s. 6d. a ton. Now the cost of fuel was a very important factor in any comparison between electrical and steam-winding, and when (as at his collieries) the value of fuel was only from 1s. to 1s. 3d. per ton, there did not appear to be much room for saving as regarded fuel. But he wanted to see where sufficient saving would come in to justify the large outlay necessary if he were to adopt electricity. Electricity was used very largely and gave great satisfaction at the collieries under his charge, for lighting, signalling and shot-firing, but he had not yet adopted it for power-purposes. They used compressed air and nothing had been put before him so far to induce him to discard compressed air for electricity either on the ground of safety or on that of economy. They had a number of very large compressed-air plants in use at their various collieries, and some were put down 14 years ago. He was at present putting down a large plant which he hoped would comprize the most recent improvements that had been adopted; it was compound and condensing in the steam and two-stage in the air, and he had spared no expense to make it as complete as possible. He would be willing to place it at their disposal for experiments as to the relative cost of electricity and of air compressed by modern plant. He wished that those present who had had experience of electrical transmission of power had given the meeting the results of their experience in actual facts and figures.

Mr. P. Barrett Coulston, replying to the discussion, said that Mr. Pope had spoken of the difficulty of working the Rateau system, but he need not say anything about that, as Mr. Preece had replied for him. He thought that he must have seen the system that Mr. Preece mentioned, and it seemed satisfactory;

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but there was some difficulty, apparently, in keeping a constant pressure of steam on the turbine. He might say that the exhaust-steam from the winding-engine was taken to a battery of old boilers, and stored there for use. Mr. Pope had referred to a projected new scheme for electrical winding which would be a great advance on the present system of supplying current; that, however, depended on the price quoted by the power-supply companies. No doubt power-companies would be ready to supply current for fairly heavy loads, at prices which it would be very difficult for private firms to beat.

There were plenty of places where the electric plant was working constantly without any break-down. In his judgment, people were as immune from break-downs with electricity as with compressed air; and electricity could compete quite favourably now with all the other systems. According to Mr. W. C. Mountain, the cost of winding would be, by an electrical system, 3s. without interest and depreciation, and 12s. 5d. with interest and depreciation per 100 tons, against 7s. 2½d. with a mechanical system; and he showed a saving of over 5s. per 100 tons in favour of a mechanical system. If those figures were correct the question arose, would the new system allow more than that? In his view, electricity was going to be the universal winding force, and that soon. With regard to the extent to which machine-cutters outdid manual labour he could only say that the results mentioned in the paper were obtained at Birtley colliery. Those who complained of breakdowns of electrical appliances must have been rather unfortunate, as their experience did not agree with that of many other persons. Touching the point raised by Mr. Pilkington, as to the need of taking off the machine when soft coal was reached, the most modern devices provided for that difficulty. All these points must, of course, be duly considered. He quite agreed that electricity was to a certain extent an untried article. None the less, he was assured that it would have a great field in the colliery-world as in other departments of life. Who would have prophesied ten years ago that they would have railways electrified? Anyone who had ventured to do so would have been considered unduly optimistic. Yet such was the fact. Over 500 miles of railway in this country were electrified during the last 12 months; and he would not be surprised to see electricity superseding the steam-engine at the colliery, as it had already superseded the locomotive on the railway

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MANCHESTER GEOLOGICAL AND MINING SOCIETY.

ORDINARY MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
MARCH 13TH, 1906.

MR. HENRY BRAMALL, PRESIDENT, IN THE CHAIR.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. HENRY HOUGHTON, Mining Engineer, Earl of Lathom's Park Collieries, Skelmersdale, Lancashire.

Mr. WILLIAM PICKUP, Mining Engineer, Rishton Colliery, near Blackburn.

ASSOCIATE MEMBER—

Mr. JAMES TAYLOR ROGERS, Mine-owner, Calder Cottage, Littleborough.

THE COURRIÈRES DISASTER.

The PRESIDENT (Mr. Henry Bramall) said that a terrible disaster had occurred at the Courrières collieries in France. He moved that the members of this Society beg to express their profound sympathy and condolence with the company and its officials, and with the relatives of the deceased miners who lost their lives in the terrible disaster at the Courrières collieries, and recognize with the highest admiration the heroic efforts of the rescue-parties.

Mr. JOHN GERRARD (H.M. Inspector of Mines), in seconding the resolution, said that they all felt a thrill of horror when they heard of the dreadful loss of life which had been occasioned—the greatest that had ever occurred in connection with mining—and they would agree that the least that a mining society like theirs could do was to express their profound sorrow and their sympathy with the large body of sufferers, and with the engineers who were

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battling, as they were now and had been for the last few days, to save life. This matter appealed to him forcibly, because it was only about five years since he had had the pleasure of visiting those mines and receiving the utmost possible courtesy and kindness at the hands of Mr. Auguste Lavaurs, the managing director, and Mr. A. Bar, the engineer-in-chief. He descended two of the mines, and for three days he had a close view of the splendid arrangements that they had established to protect life. No mining concern stood higher, he was sure, in the whole world than that of the Courrières Company, in respect of the regard that they had for the lives of their workpeople. One could not but feel that they had suffered very much indeed through this disaster coming to them.

The resolution was passed in silence, all standing.

Mr. Alfred J. Tonge read the following paper on "Underground Fans as Main Ventilators":—

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UNDERGROUND FANS AS MAIN VENTILATORS.

By ALFRED J. TONGE.

In connection with the introduction of new appliances into mines, it is interesting to notice how, what may be best described as the *locus in quo*, has changed in more or less regular order. Pumping operations were formerly conducted from the surface, now the movement strongly tends underground. Machine haulage, formerly done by steam-engines fixed belowground, was followed by hauling-engines fixed aboveground with the shaft belt-rope as a connecting link; and this only in its turn to be superseded by the electric haulage-motor fixed belowground. There is even a movement observable, which is pointing to underground compressed-air plants—one of the last that could have been anticipated. The desirability of having sources of power close at hand is only a natural corollary of the busy life that is going on beneath the surface. In ventilation, originally there was at the bottom of the shaft, a furnace, to be followed, later, by the fan on the surface, and the purpose of this paper is to show that underground fans may, in many cases, follow the same sequence.

The writer is aware that much disquietude must be quelled before mining engineers can discuss this subject with their usual calm judgment. A feeling is engendered similar to that which, at one time, must have been felt by pumping engineers, when it was suggested that pumps should be placed underground near the water. What folly, it was thought, to do such a thing and have the pump drowned! But the writer supposes it cannot be gainsaid that surface-pumps, where they are being put in, are only justifiable on the ground of economy, and not on that of immunity from immersion. A very limited period of time need be spanned to look back to the time when electric power was almost unknown in mines. There again was encountered the natural distrust of introducing an apparent menace to safety. It is a matter of common knowledge, however, that the introduc-

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tion of this new power has revolutionized methods, and so changed the aspect of collieries that coal-mining has almost appeared as a new industry.

The writer has advisedly prefaced his subject in this way in order, if possible, to take the members with greater confidence into the matter of underground ventilators.

The study of past methods of ventilation is of interest, but it would scarcely be wise to digress into them. Briefly, there was a time when every shaft that was sunk was put down for the purpose of winding, but incidentally it might simultaneously be the ventilating, pumping, and only exit-shaft. Following upon this, it may be said there were two shafts, one used for winding and one as a ventilating and second-escape shaft, at the bottom of which there was placed a furnace, or, a little later, a fan was placed on the surface. The increasing depth and cost of sinking and equipping shafts now necessitates both of the shafts being used for winding as well as for ventilating, pumping, etc.

By the system of "underground fans as main ventilators" is meant the production of the entire air-currents, coursing the mine, by fans fixed underground, and not secondary or supplementary to any surface-fan. At the Nos. 3 and 4 pits of the Hulton Colliery Company, Limited, three fans are fixed underground, one in each of three separate mines, and each fan-plant was put in with the express purpose of producing the whole of the ventilation necessary for that particular mine. The fans are so fixed that they in no case interfere with the haulage or hooking-on arrangements, and effect the coursing of the air from the top of the downcast-shaft, along the respective mines, and out at the top of the upcast-shaft, the latter being quite open to the atmosphere.

A description of the fans is recorded in Table I. The motor at the A mine is considerably too large for the work, and it will be interchanged with a haulage-motor.

In each case, the motor-pulley is so arranged that it can be changed for one of different size to suit the varying requirements of the mine. The fans are fixed in such a position that they may be said to be shunts from the main roads; and the air, in passing through the fan, does not take, absolutely, the most direct route to the shaft, the reason for which may be shown

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later. In each case, the fan-house is formed by an extension of the main hauling-enginehouse. In connection with each motor, there is a main switch, starting-switch, ammeter and fuses, while there are in each case, also, duplicate cables and suitable change-over switches. A water-gauge is supplied to each fan, connected between the suction- and outlet-sides, thus giving the full water-gauge of the mine and shafts. By a suitable arrangement of pipes and taps, the water-gauge can also be obtained of the mine only, or of the shafts only.

TABLE I.—DESCRIPTION OF THE UNDERGROUND FANS AT THE HULTON COLLIERIES.

Name of mine.	A.	B.	C.
Particulars, etc., of the fans:			
Description	Sirocco suction-fan	Sirocco forcing-fan	Sirocco suction-fan
Diameter, inches	30	45	45
Depth from surface ... ... feet	450	900	1,320
Particulars, etc., of the electric motors:			
Mode of driving	ropes	ropes	ropes
Description	three-phase	three-phase	three-phase
Power of motor ... horsepower	30	45	45
Present conditions:			
Motor, No. of revolutions per minute	740	580	573
,, ... brake-horsepower	10	31	28
Fan, No. of revolutions per minute	580	390	382
Water-gauge ... ... inches	$\frac{7}{8}$	$1\frac{5}{8}$	$1\frac{3}{8}$
Volume of air per minute, cubic feet	18,000	50,000	45,000
Anticipated conditions:			
Motor ... ... brake-horsepower	10	45	70
Fan, No. of revolutions per minute	580	480	600
Water-gauge ... ... inches	1	3	4
Volume of air per minute, cubic feet	17,500	56,000	65,000

Regarding the introduction of main fans underground, the writer does not suggest for one moment that they are applicable to every case; a necessary element of their extensive use and advantage being electricity, whereas there are many managers who may even yet (and probably justifiably so) not see their way to allow electricity to be introduced for any purpose into their mines: it would manifestly be useless to advocate electrically-driven fans in such cases. There are mines, which have reached a fairly normal output, with a spare shaft used for ventilating purposes only, and with probably only one or two seams of equal and low resistance to ventilate; and, under such circumstances, there might be some difficulty in showing any advantage. There

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must, however, be many collieries, situated as those under the writer's supervision, where the seams vary in thickness; where the present requirements in horsepower of ventilation are very light compared with the ultimate requirements; where there are several mines to work, each mine varying in the quantity of air and the mine-resistance; where the seams are thin, and the water-gauges are likely to be higher than usual; where the upcast-shaft is just as much required as the downcast-shaft for winding purposes; and, lastly, where large, economical, thoroughly duplicated electrical generators of considerable reserve-power are already installed.

In the present case, the output of the A mine is 300 tons per day, and will necessarily always remain low, as compared with the B and C mines; and it is anticipated that the same fan and motor will continue to do the work, until the exhaustion of the mine. The only alteration anticipated is that of changing the motor-pulley to suit the lengthening of the airways.

The B and C mines, it is anticipated, will extend considerably, although they have already each about double the output of the A mine. In their cases, should the output be increased abnormally, the substitution of larger motors for the present motors is all that would be required. The fans, themselves, are more elastic as to their output than the motors.

It should be stated that close to the inlet-side of the suction-fans in the A and C mines, and to the outlet-side of the forcing-fan in the B mine, an artificial resistance or regulator has been fixed, intended to represent the maximum resistance, at which each fan is to work, before an increase of the speed is required. As the mines extend, a corresponding release is made in the regulator, so that the duty performed by the fan remains constant; and this duty is fixed at a point which approximates to the highest fan-efficiency at the given speed. Plate V. shews the positions of the fans relative to the shafts.

It is an old maxim that "every inserted regulator reduces the total quantity of air"; and, while this is true, its effect is not so great in the case of three fans each running at the nearest speed to the mine-requirements, and each approximating to the highest efficiency-point at that speed, as when, say, one large fan must be running at a speed, suitable for the one mine of the

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three which has the heaviest drag, and is probably not working nearly so closely to its highest efficiency-point at that speed. In order to explain this more clearly, the writer will take the present normal water-gauges of the three mines, as follows:—A mine, $\frac{7}{8}$ inch; B mine, $1\frac{5}{8}$ inches; and C mine, $1\frac{3}{8}$ inches. It is evident that $1\frac{5}{8}$ inches is the minimum water-gauge that a large surface-fan would be required to produce, if the B mine must be equally as well ventilated as at present. As a consequence of this, in the A mine, it would be necessary to insert such an artificial resistance that the water-gauge, acting on the mine, would only be $\frac{7}{8}$ inch as at present, and the quantity of air would then be normal; in such case, the resistance must be made equal to $\frac{3}{4}$ inch of water-gauge. The C mine would also require such an artificial resistance to be inserted so that the water-gauge, acting on the mine, would only be $1\frac{3}{8}$ inches as at present, and its quantity of air would then be normal; in such case, the resistance would be $\frac{1}{4}$ inch.

As the mines are comparatively new, the loss sustained by inserting these resistances, if a surface-fan were employed, would (for the present) not be very great. The loss, however, may be more clearly shown if we assume a typical case, as is likely to accrue at the colliery under notice, or at any modern colliery working a number of seams: a total quantity of 250,000 cubic feet of air to be divided into five seams, each seam taking an equal quantity, and the water-gauges of the seams to be as follows: A seam, 1 inch; B seam, 2 inches; C seam, 3 inches; D seam, 4 inches; and E seam, 5 inches. With five underground fans, each adapted to the conditions of the mine, and yielding 50,000 cubic feet of air each, at the assumed water-gauges, the average of which would be 3 inches, the total power in the air is 118 horsepower.

Assuming the same mines to be ventilated by a surface-fan, capable of counteracting the greatest of the mine-resistances, namely, 5 inches, the remaining mines having to be regulated to an equal water-gauge, the large and increased figure of 196 horsepower in the air is obtained, or an increase for the same amount of effective mine-ventilation of 78 horsepower in the air. This 78 horsepower in the air is negative work entirely due to the insertion of regulators and amounts to an increase

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of 66 per cent. In other words, for every 100 tons of coal consumed to drive the underground fans 166 tons would be required for the surface fan. Following up these figures, and converting this increase of 78 horsepower in the air into indicated horsepower, at a combined fan-and-engine efficiency of 60 per cent., the result of 130 indicated horsepower is obtained. Assuming 2 pounds of coal to be burnt per indicated horsepower per hour, a reasonable fan-engine consumption on full loads, we arrive at a consumption of 260 pounds of coal per hour, and this amounts to 1,016 tons per annum, costing, at 5s. per ton, £254 per annum.

But this is not the only waste entailed by the use of surface fans. With the increase of depth and the decreasing thickness of seams, the water-gauges are higher. Formerly, it was thought necessary to suit the airways to the fan, now the fans are suited to the airways. Formerly, it was said that large quantities of air could not be produced without large airways. Those members who, perhaps unfortunately, have been brought up in thin seams, know that there is an economical limit to large airways, consequently, high water-gauges are concomitants of thin seams and will remain so. But high water-gauges mean greater losses by leakages through the pit-top casing, and a 10 per cent. loss on a water-gauge of 1 inch becomes, according to the rule "that the quantity of air varies as the square root of the water-gauge," 14 per cent. on a water-gauge of 2 inches; 17 per cent. on a water-gauge of 3 inches; 20 per cent. on a water-gauge of 4 inches; 22 per cent. on a water-gauge of 5 inches, or starting with a loss of 20 per cent. on a water-gauge of 1 inch, the loss attains 44 per cent. on a water-gauge of 5 inches. Moreover, at a high water-gauge, there is a depression upon all the pit-shaft openings to that amount, and this not only causes leakages at the pit-top but through every old mouthing and every crack and crevice in the shaft, which may connect with extensive old workings, etc. Even with underground fans, there may be sufficient leakages in each individual seam to justify the erection of fans working in series with one another. This especially would apply to long single airways, through "honeycombed" old workings.

The writer scarcely cares, so abnormal does this loss show itself to be, to give the figures at a shaft, at the same collieries, where a

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surface Turbo fan is fixed, working at a water-gauge of 3 inches and up to 4 inches. The actual amount of air that courses through the two working mines is actually less than 50 per cent. of the total amount of air that finds its way through the fan. This excess of air has, by reason of the high water-gauge, been drawn through what were, under a low water-gauge, inaccessible workings and mouthings, and small crevices that must accompany pit-top casings, where winding of coal is simultaneously going on.

At another mine, a surface-fan has been erected to supply air for four mines, 35 inches, 34 inches, 20 inches, and 18 inches thick respectively. The fan at 2·6 inches of water-gauge is passing 105,850 cubic feet of air in the fan-drift. The air in the mines during the ordinary hours of coal-winding only amounts to 72,870 cubic feet, a difference of 32,980 cubic feet or 31 per cent. lost by leakage. It was ascertained that of this 32,980 cubic feet of air 9,840 cubic feet was lost by the pit-top doors being intermittently opened and closed during the winding operations; and, as this was the total average loss, it is manifest that while the doors were actually opened for banking purposes the loss was much greater. Assuming that 50 per cent. of the time of winding is occupied in banking, this would give 19,680 cubic feet, as the actual loss during the time that the cage was standing at the top. There still remain 23,140 cubic feet unaccounted for; and the cause of this loss has been diligently sought. By Mr. D. Murgue's formula for obtaining the equivalent orifice, namely, $0{\cdot}403\ V \div \sqrt{h}$ in which V equals the volume in thousands of cubic feet per minute, and h is the water-gauge in inches; the writer ascertains the area of leakage to be ($0{\cdot}403 \times 23 \div \sqrt{2{\cdot}6} =$) 5·75 square feet. Now, 5·75 square feet imply a large opening, and it was self-evident that there was no single opening of that area uncovered; consequently, after searching carefully, it was found that losses were being incurred through many hidden passages. A portion has been located and stopped, and a small portion, of course, escapes through the doors even when shut; but the great body of air-loss still remains undiscovered. The loss has now been reduced to 25 per cent. The increase of water-gauge will certainly increase the loss, and there may be a time when no increase of air can be obtained underground. The 31 per cent. of loss is greater

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on small quantities than on larger: for example, on a total of 300,000 cubic feet of air it would be reduced to 10 per cent.; but, in thin seams, these large quantities are almost impracticable. An increase of volume, from 100,000 to 300,000 cubic feet per minute, through the same airways would increase the water-gauge from 3 inches to 27 inches.

The two losses on surface fans, already referred to, namely, the loss sustained by having to work all the mines at the water-gauge due to the greatest single-mine resistance, and the loss occasioned by pit-top and old-mine leakages, are supplemented in ordinary practice by a third loss, namely, the waste, accruing by the erection of a ventilating plant, which must be sufficiently large to deal with the ultimate requirements of the mine. How diverse are the ultimate requirements from working requirements may be illustrated by the mine in question. Previous to the idea of underground fans having presented itself, an estimate of the probable ultimate requirements was worked out, with the view of putting down a large surface fan, and tenders and plans were received. These requirements were supposed to be, on moderate computations, 250,000 cubic feet of air, and it was considered that not less than 5 inches of water-gauge must be allowed for. The horsepower in the air represented by these requirements is 196, and comparing this with the present quantities and water-gauges which will probably continue for some years, representing 25 horsepower in the air, the great disproportion will be noticed, the present requirements being only one-eighth of the ultimate requirements. The present work is being done by the electric generator, and this load is not only economically produced; but, being a continuous and steady load, renders the generator capable of producing a more economical load, and benefits the motors used for other purposes. Assuming that the large fan-engine to deal with 196 horsepower in the air, if fixed on the surface, were running on such a light load as would be required for 25 horsepower in the air, very economical consumptions would not be anticipated; and, while it is quite true that large fan-engines can be made as economical and smooth-running as probably any class of colliery-engine, it is nevertheless true that in many instances to-day fan-engines are running on much lighter loads than those for which they were originally

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made, and are not running to advantage and possibly never will do so, owing to the impossibility of accurately gauging the mine-conditions when ordering the fan. Of course, this objection could be minimized, even with a surface-fan, if some arrangements were made for changing the engine or motor to drive the fan, when the work upon the fan increased. It is not easy to estimate the amount of loss due to light loads on large engines, for so far, it has not been a very common practice among colliery engineers to make consumption-tests on fan or other engines, or at any rate to publish them. It would, however, be a safe computation to take an efficiency of 25 per cent. on light loads, as between the engine-output and the fan-output; in other words, if 100 horse-power were put into the engine, only 25 would be got from the fan; and this is less than half the work that the engine would do if fully loaded.

A combination of the three losses abovenamed, on any given quantity of air and water-gauges, would amount to a very considerable sum, if represented in money, at the end of the year. The writer has already given an example of the loss due to working on mines at the maximum water-gauge, as required when a surface fan is working. Assuming the same installation: namely, five mine-fans for dealing with 250,000 cubic feet of air at water-gauges of 1 inch, 2 inches, 3 inches, 4 inches and 5 inches respectively, and calculating from this the size of the surface fan, when all the pit-top and other leakages are taken into consideration, it will be found that a larger surface-fan installation is required than the sum total of all the underground mine-fans: for, assuming a loss equal to 10 per cent. on a water-gauge of 1 inch, the loss on a water-gauge of 5 inches would be 22 per cent. Consequently, in working out the surface fan, an extra quantity of air must be produced in the fan-drift, so as to leave the full 250,000 cubic feet of air for the mines, after 22 per cent. has been deducted from it for pit-top and other leakages. The quantity passing through the fan-drift must thus become 320,500 cubic feet of air per minute, or an extra quantity of air of 70,500 cubic feet. These extra 70,500 cubic feet, at a water-gauge of 5 inches, represent 55 horsepower in the air. Taking the same figures as before, namely, a fan-and-engine efficiency of 60 per cent., and a coal-consumption of 2

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pounds per indicated horsepower per hour, there is an enhanced consumption of 717 tons of coal per year, and, at 5s. per ton, the cost is £179 per annum. Added to the figures previously obtained under the heading of the first loss, this makes a combined loss of £433. The third loss described, namely, that due to the inefficiency of the engine, owing to working at very light loads, would not apply in the illustrations so far given, as the fans have been assumed, for these cases, as fully loaded; and it is not necessary for the writer to enter into any further illustration.

So far, the writer has dealt only with the question of economy, but his subsequent remarks will deal with the question of convenience and safety. Prior to the introduction of electricity it was almost impossible to adopt any system of fans underground on any extensive scale. There was then no power, at hand, suitable for underground work. Where one is able to start afresh and shake off all custom, having electricity at hand, it might not be considered good practice to encase the top of the winding-shaft during winding operations, for there are other things to be considered as well as ventilation. It is a great convenience to have both the downcast-shaft and the upcast-shaft open to the daylight, so that through inspection and examination of all the cage and rope-attachments, pit-top work, etc., can be made. It is not quite possible always to work mechanically at perfection-point, and accidents occur occasionally, whereby the pit-top casing becomes deranged, possibly by a tub protruding out of the cage; in such cases, repairs are required, and loss of ventilation meanwhile occurs. In the values of the water-gauges, so far given, there has been nothing abnormally high. It is likely, with increase of depth, the reduced thickness of seams, and the large areas to be wrought to one pair of shafts, that the water-gauges may be more than doubled. In this way, one would only be following many Continental collieries. At one large colliery, in Westphalia, visited by the writer, the normal water-gauge was 7 inches, and the maximum, 11 inches, and two complete duplicate plants were erected. At another colliery, owing to the high water-gauge, 14 inches, and the fact that coals were wound at the upcast-shaft, great expense had been entailed in keeping the pit-top tight, for the whole of a

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large pit-brow was girdered and concreted closely round and over, an air-lock being formed by means of a water-veil at the lower end of the coal-screen. In most of the collieries visited, quick running duplicate high water-gauge fans, were the rule.

The convenience of being able to regulate the supply of air in one mine as in the case of the underground fans, without affecting any other, is also of some value.

Regarding the question of safety, the writer is aware that there is a strong and a well-grounded antipathy to the suggestion of placing fans underground, and this he does not wish to condemn. The amount of precaution to be taken is a matter for each responsible individual. There are already colliery-owners and managers in this country who consider it necessary to have two surface fans, so that in case of emergency the ventilation may be quickly resumed. There are other collieries, where, as far as possible, the steam-pipes and parts of the engine are duplicated; but trust is placed on the one fan. There are also collieries with a surface fan, and with smaller, so-called, auxiliary fans underground. Looked at from one standpoint, they are rightly termed auxiliary, as they do not effect the whole of the ventilation. They may, however, be effecting the whole of the ventilation beyond a certain point in one district; and these so-called auxiliary fans then become vital to that part of the district: for in all probability, the surface fan, should it be called upon, could not possibly penetrate, with effect, into that district, owing to its lower water-gauge power, as possibly the required depression would be higher than the static water-gauge of the fan. These auxiliary fans may be as important as the main underground ventilator, which is situated in a mine of only moderate dimensions.

The writer is of opinion, however, that suitable precautions should be taken, with the view of restoring the ventilation in case of an explosion which may damage the underground fan. At the Hulton colliery, the underground fans have given complete satisfaction from an economical and reliable standpoint, and precautionary measures have been adopted, whereby, should an explosion or some unlooked-for stoppage occur, the fans being shunts from the main-airways and having escape-doors fixed in suitable positions, there will be a tendency for the fans to remain

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uninjured. It is, however, the intention of the Hulton Colliery Company, in order to "make assurance doubly sure," to erect a complete installation at the surface, to act entirely as a standbye to the underground fans. It will thus be possible to have all the benefits of a main underground-fan installation and none of its possible disadvantages. In this case, the surface fan will be barricaded, and the pit having an open top there will be even greater immunity from wreckage in case of explosion than if the surface fan were working on the mine at the time. The cost of this dual arrangement would not be anything like so great as two duplicate plants fixed on the surface, for the small underground motor-driven fans do not entail anything like the cost of one first-class large single surface plant; and the cost of the surface standbye plant, while being absolutely as reliable and sound as possible, need not be put down to give the best possible steam-consumptions, as it would only require to be run occasionally. The cost of this plant could then be reduced very considerably. Even if the extra cost of the underground and surface standbye combined were, say, £1,500 above the cost of one complete surface-plant working continuously, the interest and depreciation of this amount at 10 per cent. is £150, and this would still leave, after allowing for the saving in working, a substantial amount per year to the credit of the underground fans.

In case a surface fan is to be run, special arrangements will be made to cover over the pit-top; and this will be ready, so that at a few moments' notice the standbye fan can be run on the pit, without interfering with the winding of men.

Embodying the foregoing facts and theories together in a summarized form, the writer has tried to show that there are certain conditions favourable to underground fans:—

(1) Where there is an absolutely reliable and well-duplicated generating electrical station of considerable dimensions and sufficient available power.

(2) Where the upcast-shaft is used as a winding-shaft.

(3) Where the mines are thin or the airways long and "honeycombed," and the water-gauges are high.

(4) Where there are a number of mines with varying water-gauges.

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(5) Where proper precautions are taken for restoring the full quantity of ventilation quickly, in case of damage to fans by explosion or any unlooked-for stoppage.

If underground fans are properly installed and reasonably worked the writer would expect to obtain, and the Hulton Colliery Company have already obtained, the following conditions:—

(1) Greater elasticity in suiting the fan-speeds and quantities to each individual mine.

(2) Greater economy, because (*a*) there is no loss whatever from leakages, and 100 per cent. of the air that enters the shaft is put to useful work underground; (*b*) no air is drawn unwittingly from old workings in other seams; and (*c*) the fans and motors are working more efficiently, owing to compliance with the first of the conditions.

(3) There is an open pit-shaft for winding and examination purposes.

(4) There is a greater margin of safety, because there is less risk of a long stoppage, and because there is a duplicate plant as a standbye.

The writer repeats that the question of the adoption of underground fans is largely one for the individual owner and manager. For many years, while thick seams have been so much in vogue, large fans producing large quantities of air at low water-gauges have been very popular and convenient. Their reliability, smoothness of running, and beautiful action, had been one of the triumphs of the mechanical engineer, and it would be futile for anyone to say that large slow-running fans have been out of place, or that they would be quickly superseded. The writer's purpose has been to show an alternative method for deep and thin mines, having necessarily attenuated airways of restricted area; and where electric power and other suitable conditions are available, there can be no doubt of the utility and economy of the plant. It may be, or it may not, that the question of economy is being overdone at the present time, but this should not mean that ventilating plant should be only the "Cinderella" of colliery-work and left out of consideration.

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The PRESIDENT (Mr. Henry Bramall) said that the members were all very much indebted to Mr. Tonge for the able paper which he had brought before them and he moved that a vote of thanks be given to Mr. Tonge.

Mr. J. S. BURROWS, in seconding the motion, enquired as to the attendance to the three fans at the week-end, say, from Saturday to Monday morning.

The resolution was passed.

Mr. ALFRED J. TONGE said that there was no direct attendance on the fans at the week-end. They were watched very carefully from the generating station, and a man was sent down from the surface about every 4 hours. The oiling arrangements were good, and the fans gave very little trouble.

The further discussion was adjourned.

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MANCHESTER GEOLOGICAL AND MINING SOCIETY.

ORDINARY MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
APRIL 10TH, 1906.

MR. HENRY BRAMALL, PRESIDENT, IN THE CHAIR.

The following gentleman was elected, having been previously nominated:

MEMBER—
Mr. AUSTIN HOPKINSON, Mechanical and Electrical Engineer, 86, Cross Street, Manchester.

DISCUSSION OF MR. ALFRED J. TONGE'S PAPER ON "UNDERGROUND FANS AS MAIN VENTILATORS."*

Mr. WILLIAM OLLERENSHAW wrote that Mr. Tonge had from time to time read several valuable papers before the Society, but he had excelled all his previous efforts in the paper now open for discussion. He believed with Mr. Tonge that the underground ventilator would be found in the future to be as advantageous as the underground pump was now found to be in mining coal or any other mineral. In the matter of leakage, where surface fans were used for ventilating, Mr. Tonge was not alone in his experience of the loss between the blades of the fan and the quantity of air circulating through the working-places of the mines; and, however well designed and fitting the casing of an upcast winding shaft might be at first, the constant strain to which it was subjected soon tended to render some parts of the casing defective, and when the leakages from old workings, etc., were added to the above loss it often meant a great percentage of the total amount passing through the fan. He (Mr. Ollerenshaw) had erected a similar fan to

* *Trans. Inst. M. E.*, 1906, vol. xxxi., page 207.

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those referred to by Mr. Tonge; but, not being at that time in possession of electrical power, he was compelled to place the fan at the surface. Although it was placed at a pit where no winding of men or mineral took place, thus permitting of the top of the shaft being closed by tightly fitting clap-doors, the amount of air in the main intake-airway was about 25 per cent. less than the quantity in the fan-drift, owing to the leakages in the upcast-shaft from old workings, etc. He believed that, if this fan had been placed at the bottom of the upcast-shaft, at least 95 per cent. of the air passing through the fan would have been obtained in the working-places of the mine. Another advantage, not referred to by the writer of the paper, was obtained by placing the fan underground, namely, that the fan was not subjected to the constantly varying conditions of weather experienced in this country. When properly fixed underground, a fan should have a much longer life, and require considerably less repairs than if fixed on the surface. In supporting this method of ventilation, he (Mr. Ollerenshaw) wished it to be understood that he did not recommend that the old type of large heavy fan should be used, which required heavy foundations and large houses for their use; but that fans of light construction, running at high velocities and capable of passing very large quantities of air, should be used.

Mr. A. Dury Mitton wrote that Mr. Tonge's paper certainly gave mining engineers information that opened the door to a great alteration in the method of ventilating mines in the future. The question of forcing air into the mines had been very successfully adopted in Scotland at large collieries which he had inspected, and where there were large goaves, giving off quantities of black-damp, which could not be removed by the usual method of drawing the air through a fan. The capital outlay by Mr. Tonge's plan would be cheaper, in first cost, than a large fan on the surface. Mr. Tonge did not give any information as to the back pressure of the air on the fans in the upcast-shaft, and this, he thought, when divided over three fans, would cause considerable resistance. One great feature in adopting Mr. Tonge's plan would be the clearance of the upcast-shaft from all obstructions, and thereby great leakages of air would be prevented. Against these advantages, there must be con-

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sidered the question of damage in the case of explosions, and the impossibility of quickly restoring the ventilation so as to rescue life.

Mr. CHAS. PILKINGTON said that Mr. Tonge suggested that fans should be high running, and light in construction. Everybody nowadays was going in for high-speed machinery; at the same time, much might be said against that, especially in the case of light fans. Heavy, or comparatively heavy, fans ran with less breakdowns than high-velocity light fans. From his experience he should say that small, light fans were much more difficult to manage, and that they required more power than many people imagined. Hence, he did not think that they ought to go to too great an extent in this direction. He did not quite see the advantage of placing the fan in the mine; but they would, in that case, do away with all the top plant required in the case of the ordinary fan.

Mr. JOHN GERRARD (H.M. Inspector of Mines) said that in recent years the question of underground fans had come to the front; and, although this was the first paper as yet brought before mining engineers, it deserved serious consideration. It appeared to him that Mr. Tonge had dealt with the subject solely from an economical point of view, and in so doing he had taken risks which were open to criticism. For instance, there were five seams, in three of which were underground fans. At week-ends those fans were not under close supervision; perfunctory, occasional visits were made from the surface, he thought, every 4 hours; the electric current had to be on the whole time; and if any accident occurred, say, from a short circuit, the mischief might be beyond control when discovered (the Ashton Moss colliery engine-house was a roaring furnace in 20 minutes from the short-circuiting of a lighting cable). Let them consider for a moment, if there were five fans requiring five attendants underground, compared with one fan at the surface involving one attendant, surely that was a point in favour of surface fans. In dealing with the economy of fuel, its value was taken at 5s. per ton: when, at a recent meeting, electrical engineers valued colliery-consumed fuel at 4s. a ton, it was critically questioned, and one speaker stated that 1s. 6d. per ton was the value of his. One of Mr. Tonge's strong points in favour of underground

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fans was the great loss of air from short-circuiting in surface fans at the top of the upcast-shaft. With high water-gauges, limited quantities of air, wire-drawn conditions, this loss was very remarkable; but these were the conditions that mining engineers in this country did their utmost to avoid. Perhaps the most important thing that his forty years' mining experience had taught him was the importance and value of good large roads. Mr. Tonge gave the quantity of air for his five seams as 113,000 cubic feet per minute, the output of coal was 1,500 tons a day, and two of the seams were the most fiery in the district—the Arley and the Trencherbone. To him, the remarkable feature in all this was the small amount of air. He ventured to think that, with a good big volume of air and a low water-gauge, the loss from leakage at the top of an upcast-shaft would be comparatively negligible. He wanted to be perfectly fair. From that one point of view the convenience of an open-topped upcast-shaft compared with a close-topped shaft was very great. If other points could be met, this told greatly in favour of underground fans. There was another reason for considering underground fans. They were deepening the shafts, with higher temperatures requiring sweeping currents to cool sufficiently the men at work, extending the royalties and increasing the distance from the shaft. It seemed to him that there was a distinct opening for the use of underground fans as auxiliaries to the surface fan, to push on the ventilation. That brought him to the chief problem in connection with fans underground, to which he invited mining engineers to give serious consideration. Could a fan be so placed underground as to be available after an explosion? Our mining laws required this to be considered. After an explosion, the first duty is to endeavour to rescue from the mine all possible survivors. To do so, the first requirement is to have full command of the ventilating apparatus. If that ventilating apparatus could not be used, if it were wrecked, if it could not be got at, the first line of defence fails. How had Mr. Tonge met this difficulty? Only a pass-bye, in the main road a light barricade of wood, ordinarily this deflected the air-current to the fan, the theory being that an explosion would sweep away this barricade, the force of the explosion passing by the entrance to the fan-chamber. Was there a single mining engineer, having had experience of the terrible

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wrecking effect of a modern coal-dust explosion, who would say that Mr. Tonge's proposal met the case? A much more effectual protection to the underground fan would be to wet thoroughly the roof, sides and floor of the roadway for 300 feet on every side of the fan. With reference to the Coal-mines Regulation Act, he thought that if a case could be established in favour of fans underground, by reason of greater efficiency, after full protection, the law should permit this to be done.

The PRESIDENT (Mr. Henry Bramall) thought that the question might be put in a very narrow compass, and might be considered from the points of view of safety and of economy; and the discussion might very well be limited to those two points. Speaking from his own experience, he agreed very much with what Mr. Gerrard had said on the question of safety. Mr. Tonge suggested that the underground fans should be protected by being placed in certain bye-roads; and Mr. Gerrard had very properly pointed out that no such roads were free from the effects of an explosion, which, as a rule, affected all the corners of the mine. Mr. Tonge's plan, therefore, would not be effective in the event of an explosion, as the fan would be destroyed. The danger of fire from an electric current might be obviated by using compressed air or steam as the motive power, but the answer to that would seem to be that there was no economy in such a proposal. Mr. Tonge was of opinion that it was only by the use of electricity that they would get economy. He (Mr. Bramall) failed to see where the economy came in, if there were proper attendance on the fans. The seven fans suggested would require 14 men to attend them at the least, and probably 21 men. His own view was that a fan on the surface was much safer than one underground, being much less liable to damage from explosion and much more likely to be efficiently maintained. If reliance were placed solely upon the underground fan, and this fan were blown away by an explosion, he (Mr. Bramall) did not see how it would be possible to restore the ventilation. On the question of leakage, from the shaft-mouthing of an exhausted seam, he would not, for his own part, care to stop off absolutely such an old working. He would prefer that a little leakage should take place, for one could not say what might occur. Mr. Tonge had suggested that a duplicate plant

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should be erected on the surface for safety. It seemed a large order, to put a costly fan underground, and then, to ensure its safety, to put another plant on the surface. He did not see any economy in that plan. He thought that one large fan would probably be worked more economically, all other things being equal, than a number of smaller fans placed in different seams. The principal advantage that he could see from Mr. Tonge's proposal was the facility of using the upcast-shaft for winding purposes. It was a little inconvenient, and the same quantity of coal could not be wound through a shaft cased in at the top as with a free and open shaft; but that advantage was more than counterbalanced by the risks involved by putting the fans underground. Of course, they all knew that machinery underground was apt to be neglected. The tendency had been to put the fan aboveground, because there it was more economically worked and better looked after, with less risk from accident. He did not think that fans underground would be kept up to the same degree of efficiency as fans placed on the surface, where they could be better attended to, and more easily kept in proper order.

Mr. William Watts said that he was engaged in driving a tunnel, 4 miles long, which was ventilated from the two ends by means of exhaust-tubes, 20 inches in diameter, the atmospheric air travelling up the headway to the working-faces. The air travelling up the headway could not exceed in amount the cubic feet of air exhausted per minute; he agreed with Mr. Gerrard that the greater the headway the greater the volume of atmospheric air that would travel along it—but, of course, at a reduced velocity, unless the exhaust-fan or shaft were increased accordingly. It was a question of the supply meeting the demand, whether the openings be large or small. In the tunnel-ventilation to which he referred, there was no movement in the water-gauge, probably because the exhaust-velocity in the tube was too slow, and intermediate fans would have to be erected to increase it, as the ventilation was not satisfactory at a distance of 4,800 feet in the headway. What the results would be of this method of ventilation, when the driving had reached 10,560 feet, he could not say. The compressors, however, kept the air pure at the working-faces when the power-drills were working. At times, he noticed that the amount of air delivered under

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pressure was more than the tubes could exhaust, and it had to diffuse itself in the heading and thus checked the headway flow. Nevertheless, from the tunnel-entrance to the point reached by the foul air, the atmosphere was invariably very clear

Mr. George H. Winstanley complimented Mr. Tonge on his paper. It was exceedingly interesting, and from the writer's point of view the advantages claimed had been admirably demonstrated. Of course they had to remember that Mr. Tonge's remarks had special reference to the Hulton collieries, which appeared to be well suited for the particular arrangement advocated by the writer, who had apparently to his own satisfaction achieved the objects in view, namely, a clear shaft for winding; economy resulting from the fact that a certain portion of the ventilating volume was dealt with at a lower water-gauge than the maximum prevailing in other parts of the mine; and reduced leakage. With regard to the last-named point, he (Mr. Winstanley) agreed with Mr. Gerrard, that the most effective way to avoid excessive leakage was to provide airways of large area, so that the ventilating pressure might be as low as possible. He thought, however, that Mr. Tonge could not expect much sympathy. In connection with mining there were three essential features, and like the three graces, Faith, Hope and Charity, of which the greatest is Charity, they had efficiency, economy and safety, and the greatest of these is safety. While they strove for economy, it must never be at the expense of safety, or at the risk of reducing conditions tending towards safety. They occupied, in the Manchester coal-field at the present moment, a proud position with regard to fatalities from explosions. He believed he was correct in stating that, during the last official year, not only had there not been a single fatality from explosion, but there had not even been a single ignition of gas in the collieries in the Manchester mines-inspection district. They must remember how that most desirable condition of things had been attained, and endeavour to avoid a retrograde movement. They were all well acquainted with the history and the records of colliery-explosions, they knew how steadily and gradually the tremendous death-roll of former years had been reduced, until, for the moment at least, they had a clean sheet. This improvement was largely to be attributed, he (Mr. Winstanley) thought, to improved systems

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of ventilation and the employment of more powerful and more perfect appliances. One great advantage of the fan, as compared with the furnace, was the fact that it could be put to work on the surface out of harm's way. Mr. Tonge had compared the introduction of the fan as an underground ventilator with the modern tendency in connection with pumping, hauling and other operations, but particularly pumping. He (Mr. Winstanley) thought that the conclusion was scarcely logical. The tendency with regard to the pump was to take it to the place where the water was, and where the work had to be done; with the fan it was different. The fan was concerned with the atmosphere, of which the unlimited supply, for the purposes of ventilation, was on the surface; and the surface seemed to him to be the proper place for the fan. The suggestion that the ventilator should be taken underground, because the pump had found a place there, seemed to him to be scarcely sound reasoning. There was the further question, alluded to by Mr. Gerrard, of leaving the ventilators and their motors unattended during week-ends and other intervals. It was, he thought, a somewhat risky proceeding to leave electrical appliances working underground in a mine absolutely unattended. Personally, he was enamoured of electrical power-transmission in mines; and whilst electrical appliances, under proper supervision, might be employed with every confidence, at the same time electricity was a form of energy which one would scarcely choose to leave unattended in the workings of a mine. Mr. Tonge seemed to have anticipated this objection, and had reminded the members that anything going wrong would be immediately indicated on the switchboard in the power-house. When the indication was given that something had happened underground, it might be too late to take measures to prevent a still greater disaster. There was just the saving clause that if the fans or motors did go wrong at the week-end, when the mine was not working, no men would be underground and therefore no lives would be jeopardized: the damage would be confined to plant and property, although, possibly, few proprietors would care to incur even that risk. Whilst complimenting Mr. Tonge on the manner in which he had handled his subject and demonstrated certain advantages, he (Mr. Winstanley) considered that the element of safety must of necessity outweigh and take precedence of all other advantages; indeed,

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if conditions of safety were amply provided for, it would generally be found that efficiency and economy were embraced by those provisions.

Mr. JOHN LIVESEY said that it seemed to him that Mr. Tonge's idea in writing the paper was to develop the split system of ventilation, and he would be able to get a more sweeping ventilation by putting a fan in each split than by putting one on the surface, and checking the ventilation by a number of regulators in the shorter splits.

Mr. ALFRED J. TONGE, replying to the discussion, thanked the various speakers for their courtesy and criticisms. With reference to Mr. Gerrard's remarks, he felt some diffidence in answering him as fully as he would like to do on this occasion. Still, he thought that Mr. Gerrard would excuse him if he said that in the latter part of his remarks his critic was more friendly to the paper than he appeared to be at the beginning. Mr. Gerrard had spoken of the arrangement for the protection of the fans as more or less a matter of form and fulfilling no useful purpose. Well, it seemed to him that to carry out the law as it was now, any person wishing to put an underground fan in the mine, whether as an auxiliary or a main fan, must make some attempt to safeguard it in the event of an explosion. The law made no proposal on the subject; it simply stated that when a fan was put in it should be so placed "as will tend to ensure its being uninjured by an explosion." Consequently, if any auxiliary fans were put in, there must be some arrangement of the sort that he had mentioned, so as to protect them from the effects of an explosion. That was why he resorted to these protective plans—it was to keep himself within the requirements of the law. He thought that his arrangement would help to reduce the damage to the fans in the event of an explosion. He did not see why a slip-way underground should not act somewhat in the same way as a slip-way on the surface: for, after all, closing in a pit-top on the surface was only closing in the airway, and if a stopping in an airway could be made in such a form that it would yield at a slight increase of pressure, probably the fan, fixed in the bye-pass road, would be saved. It seemed to him, as regards possible damage to underground fans, that he met the objection by adopting a surface stand-

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bye fan. He would like the members to recollect that he had made a point of this in his paper. The fans had been working for 2½ years, and, so far, experience had shown that the supervision had been quite sufficient. Any irregularity in their working would be at once noticed by the engineer, who was in constant attendance at the power-house switchboard. This was quite in accordance with the spirit and letter of the Special Rules for the Installation and Use of Electricity (section I., No. 11), and any question of a fire ensuing was one of the ordinary precautions which required full thought; but it did not come under the purview of his paper. The Special Rule recognized that it was unnecessary to have a constant attendant underground and only stipulated that there should be one when the amount of electricity delivered down the mine exceeded 200 brake horsepower. There was room to look at the question of economy from two sides. It was not his intention to make too much of the monetary side. They wanted to economize their air: having put up the fan, the object was to get the same quantity of air in the workings that the fan was passing, and it was contrary to safety not to obtain all that air. It was not enough to see that they got the air through the fan only, but it should pass where it was wanted. Members knew how difficult it was at times to get the air at the extreme corners of the workings, and when a large surface slow-running fan had reached its maximum output it became a very serious item of expenditure if a larger surface fan had to be substituted. To avoid this heavy expense, which was an inducement to continue working under these unsatisfactory conditions, he suggested that at points, where the air was slow, fans should be put in, and if mine managers knew that they could be economically and reliably worked, and also if they knew that there was no conflict with the spirit of the law, they would be more inclined to do so. Even where no other safeguards had been adopted, he thought that it was far better to prevent explosions by proper distribution of the air, than to neglect those proper means of distribution in thinking too much of the difficulties that might arise afterwards. He had in mind a case where a mining engineer could not get the air that was needed in the workings. There was a water-gauge of 8 inches. Do as he would, this gentleman could not get through the workings by his surface fan anything like 50

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per cent. of the air, and that was because of the honeycombed old workings. It seemed to him that the only solution of that question was to put the fans in the mine. If a manager were expecting to have 100,000 cubic feet of air through the workings, and could not get more than 25,000 cubic feet, he was in a difficulty that could probably only be overcome by the use of underground fans. He (Mr. Tonge) was afraid that Mr. Watts had not quite caught the idea of his paper. In this particular mine, there were two shafts, so that it was not a question of saving space in the shaft; but it was a question of saving the loss at the pit-top and other places. With regard to the question of the number of mines, he supposed that there was nothing that could not be reduced to an absurdity, but he would like to say that there were very few collieries which would have seven separate mines working. Where such was the case, the separate workings were probably linked together and brought to two or three common mouthings. For instance, in the Hulton colliery, instead of having three mines, A, B and C, there were actually five for the three fans, as the B and C mines each consisted of two seams. On the question of the cost of underground fans arranged with a duplicate plant on the surface, he (Mr. Tonge) expressed the opinion that the advantage lay with that system rather than with one that involved two complete plants on the surface. Where there were underground fans, the stand-bye plant on the surface would not need to be so elaborate and costly as if it were the sole resource of the colliery. He assured the members, in conclusion, that with him the question was of first importance, and in his opinion, greater safety was secured by having underground fans and a stand-bye surface fan, than by having a surface fan only.

DISCUSSION OF MR. P. BARRETT COULSTON'S PAPER ON "THE USE OF ELECTRICITY IN COLLIERIES."*

Mr. GERALD H. J. HOOGHWINKEL considered that Mr. Coulston's paper was a very important one, and he agreed with most of the points that Mr. Coulston had put before the members. He thought that most of the members would agree that electricity was preferable, and would be preferred gradually for all such

* *Trans. Inst. M. E.*, 1906, vol. xxxi., page 185.

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purposes as coal-cutting, haulage, pumping and drilling; and the only outstanding point on which opinions differed very much seemed to be electric winding. Mr. W. C. Mountain (in a recent paper)* came to the conclusion that electric winding would perhaps pay for a small output, or a combination of small collieries, but would not pay for a large daily output. His experience was completely at variance with that statement; and he desired to put before the members some points which showed that the comparison cited by Mr. Mountain was not correct. It was a general one, and most mining engineers were likely to agree to it. Taking the list of collieries, detailed by Mr. Mountain, it would be found that the cost per 100 tons varied from about 5s. to something like 10s. At the same time, the cost of the coal burnt varied from 1s. 6d. to about 5s. per ton, and the depth from which the coal was wound varied from 600 to 1,650 feet. A comparison of this kind must always be wrong, because the principal point was the depth from which the coal was wound, and the cost was obviously greater when the depth was greater. On these grounds, therefore, the comparison between the cost of steam and electric winding failed. The only safe way of comparing must be by comparing the amount of useful work in horsepower-hours. It might, at any rate, be taken as a fact, that the dearer the coal the better was the case for electricity; and for that reason electricity was much preferred on the Continent. On the Continent, better coal was used for their boilers than was usually employed in Great Britain. Dirt and very small slack was not burnt as was done in this country, and he (Mr. Hooghwinkel) thought that it was the right policy. Such fuel was not fit for boilers: it should be put into coke-ovens or gas-producers, and used to generate electricity and make coke. He also wished to correct the idea that a separate electric plant was necessary for winding purposes. No one would think, so far as his experience went, of putting up an electric station for winding purposes only. At the collieries with which he was connected, more electricity was used for hauling, pumping and all other power-requirements than for winding alone; and the same was true of Germany. Therefore, in calculating the working cost of an electric winding installation, they must have the

* "Electric Winding in Main Shafts considered Practically and Commercially," by Mr. W. C. Mountain, *Journal of the Institution of Electrical Engineers*, 1906, vol. xxxvi., page 499.

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number of units required for a certain output per day. If the output were taken at 100 tons, the number of horsepower-hours required to lift it from a certain depth could be calculated, and from this the units required from the power-station. There were several power-stations in this country, and the facts as to cost, etc., were available, so that colliery proprietors need not grope in the dark in considering questions of electricity as applied to colliery-working. For a colliery power-station, of a fair size, a cost of 0·25d. to 0·30d. per unit may be taken, using turbines or gas-engines.

Another point that he wished to emphasize was that electric plant was not so complicated as it looked, not even so much as an ordinary steam winding-engine. Surely a simple revolving motor was not as complicated as a steam-engine. On grounds, therefore, of efficiency, economy and simplicity, he submitted that electricity was preferable to steam for coal-mining purposes.

Mr. W. C. MOUNTAIN wrote that Mr. Coulston's paper was one of those practical papers which go so much to help the progress of electric work amongst collieries, and as he had for the last 18 years made the application of electricity to mining one of his principal studies, he was able, he thought, to speak with some amount of certainty on this subject. The application of electricity to colliery-requirements in the future depended entirely upon the commercial aspect of the case, and he felt that it was of no use putting forward possibilities and probabilities unless the information were so combined that the probable saving or the return on the capital expended could be clearly shown.

He noted that Mr. Coulston dealt with electric winding, and some misconception seemed to have arisen in the minds of electrical engineers as to his (Mr. Mountain's) recent remarks and papers on this subject. He wished it to be clearly understood that he was by no means an opponent of electric winding, but a strong advocate for its use where the circumstances were such that a commercial saving could be shown. It must, however, be borne in mind that the principal application for electric winding in the near future would be at new collieries, where the tendency was to greatly increase the output, and where, from very great depths, it would probably be necessary to wind 2,000 to 2,500 tons in 8 to 10 hours; and it was upon such heavy duty that he questioned whether electricity could be economic-

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ally applied. Under such circumstances, it was quite possible that the power required for winding would be two or three times as great as the whole of the other power required, both for surface and underground work. This would involve a very expensive generating station, which would be idle for two-thirds of its time, and if the Ilgner or the motor-generator method of winding were used, it would further necessitate keeping the generating plant at work for the whole of the 24 hours in order to keep the motor-generator running, in case it were necessary during the night, or when the pit was off, to lower men, timber, or other materials down the shaft. The figures, contained in his (Mr. Mountain's) recent paper,* read in Manchester and also in London, were based upon these conditions, because he maintained that they were the conditions most likely to exist in modern collieries. In smaller collieries, or in groups of collieries where the power required for the winding was only a small proportion, or probably half of the whole, or where the power could be taken from a central generating station, he thought that there was an excellent prospect of electric winding being economically adopted; because, as could be gathered from his papers, the actual cost of winding electrically (apart from interest and depreciation) was rather less than with high-class steam winding-engines; but the heavy cost of interest and depreciation on the winding-plant killed the system. Mr. Coulston had stated that, in his opinion, the costs which he (Mr. Mountain) gave for electric winding were distinctly high. In his opening remarks† in London he distinctly stated that the main object of the electrical engineer must be to reduce the cost of the electric plant, and this he again repeated; but he might point out that Mr. Coulston did not give any figures which he considered correct.

The only attempt that had been made, so far, to combat his figures had been by Mr. A. S. Clift, who advanced other figures, but he (Mr. Mountain) questioned their accuracy. Mr. Clift stated that the cost of the electric winding-gear, comprizing a motor of 1,000 horsepower, a flywheel running in two bearings, a generator capable of giving 3,000 kilowatts, together with the main switchboard, the connecting cables, an exciter for the generator, the cables between the motor-generator and the winding-gear,

* *Journal of the Institution of Electrical Engineers*, 1906, vol. xxxvi., page 499.

† *Ibid.*, page 499.

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together with a switchboard and two motors, each capable of developing 1,500 horsepower on the winding-gear, was £9,000. He also stated that a generating plant, or the proportion of a generating plant, of 1,000 kilowatts' capacity should be valued at £3,000; and this figure in his (Mr. Mountain's) opinion was impossible. Mr. Clift further stated that he proposed to run this plant with two boilers, which he (Mr. Mountain) considered were too few; and he valued two boilers 30 feet long and 9 feet in diameter, along with steam-pipes, feed-pumps, feed-pipes, proportion of condensing apparatus, etc., at £2,000; and this figure was again much less than the boilers, etc., could be purchased for, put upon their seats, and erected. He (Mr. Mountain) might say that his estimates were most carefully calculated, and whilst he hoped that a small reduction in the cost could be made, he did not personally feel that any very great reduction could be made, unless it were done by forcing up the speed very considerably, and this was really the ground upon which Mr. Clift based his figures. He was sure that all colliery managers would agree, and most electrical engineers also, that any excessive speed about winding machinery, or the plant in connection therewith, was to be deprecated, as reliability was the most important item.

His (Mr. Mountain's) views, as regards electric winding were as follow:—(*a*) Electric winding could be usefully applied to existing collieries of small output, where the steam-machinery was out of date and required renewal, and it was proposed at the same time to electrify the pit generally, that is, the pumping, hauling, screening and surface-driving, and (possibly), coal-cutting. (*b*) Electric winding could probably be used in collieries of medium and possibly large output, with advantage, where the current supplied might be obtained from a power-station at a low price; and where it was also proposed to level the load by the use of motor-generators, in connection with the winding-gear and the application of electricity to all other purposes about the colliery. (*c*) For large isolated collieries, where winding absorbed two or three times the amount of power required for driving the surface and underground work, and where steam was available and could be produced by waste or cheap coal, he thought that steam-winding would be found more economical, as regards running costs, than electric winding. The whole problem as to whether electric winding could be economically

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adopted depended upon several factors, namely, (1) the cost of the coal available for the boilers; (2) the depth of the shaft; (3) the capacity in tons per hour; (4) the amount of work to be done on the colliery, apart from the question of winding; and (5) whether it was possible to obtain a supply from a power-station, and if so, at what cost per unit. With these facts presented, careful estimates could be made; but it was impossible to lay down any hard-and-fast rule as for what power or for what depth electric winding could be usefully applied, without considering all the surrounding circumstances.

Mr. Coulston, in his paper, had touched on the application of electricity to haulage, pumping, coal-cutting and surface-driving, including fans, and he concurred entirely with Mr. Coulston in stating that for all these purposes the use of electricity was the only economical means of driving which could be adopted, particularly where the machinery was placed at some considerable distance from the power-station. Enormous economies had been, and could be, shewn where electricity had been judiciously applied, and there was no question that it rendered the working of collieries much simpler and safer, and greatly reduced the cost of working.

The use of gas-engines, particularly in Welsh collieries, where anthracite-coal was available at low cost, appeared to show great possibilities. His firm were installing two large gas-engine plants in connection with mines at the present time; but, in order to ensure the greatest possible reliability, they were, in all cases, advocating the use of three engines, that was, on full load, the three engines could be run slightly under-powered. In case of emergency, two engines would carry the full load, the third set being a stand-bye, and whether it were steam or gas, he strongly advocated this division of units for all colliery-requirements. It was, however, very questionable whether large gas-engines could be regarded as really reliable. The upkeep was no doubt considerably greater than with steam-engines, and it was necessary to take the above-mentioned precautions, if gas-engines were to be adopted.

He (Mr. Mountain) was very glad to note that the Special Rules for the Installation and Use of Electricity had already had a considerable effect, and that it was now recognized that electrical machinery, underground particularly, required proper looking after by those in charge. He did not mean that expen-

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sive labour was required; but competent men, who understood sufficient to look after the machinery properly, must be in charge. His own experience was that electrical machinery, even in the hands of men who knew nothing about electricity, but who were prepared to keep the machinery clean and to look after it carefully, gave great satisfaction, and the upkeep was extremely small; and he had found that men calling themselves electricians, and who knew just sufficient to make them careless and neglect cleanliness, were frequently the worst class of men to look after this type of plant.

Mr. Hooghwinkel seemed to lay great stress upon what he described as the consumption of steam per useful horsepower. By useful horsepower he understood that Mr. Hooghwinkel meant the average horsepower, over the working-day, required theoretically to lift the coal from the shaft-bottom to the surface. He (Mr. Mountain) maintained that to speak to colliery owners or mining engineers of the amount of steam used per useful horsepower was merely a waste of time. It really conveyed very little information, for the simple reason that in a shallow pit, where the number of winds was considerable, the actual horsepower required on the rope, due to the power necessary for acceleration and other losses, would probably be at least double (or more) the horsepower theoretically necessary to do the work; and, in deeper pits, he found that the horsepower on the rope was about 1½ times the theoretical horsepower. It was, therefore, impossible to make any use of the term "useful horsepower," unless the depth of the shaft and the working conditions and the losses arising from these conditions were understood. He agreed with Mr. Hooghwinkel that electric winding became possible at pits where the cost of fuel was considerable; but what the actual costs should be, depended principally upon the cost of the electric winding-plant as compared with the cost of the steam-winder. In the list of collieries, given in his (Mr. Mountain's) paper on electric winding,* he selected twelve typical collieries, so that the greatest variations both in cost, winding depths, and other particulars should be shewn. Some of these collieries might probably adopt electric winding with advantage, whereas others, differently situated as regards output and cost of coal burnt under the boilers, could not adopt electric winding with any possible advantage.

* *Journal of the Institution of Electrical Engineers*, 1906, vol. xxxvi., page 499.

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He agreed with Mr. Hooghwinkel that, at a colliery where the electrical plant was of fair size and the load on the generating station was practically constant, electricity could be produced at a cost of 0·25d. to 0·30d. per unit; but, in his experience, at colliery-installations of smaller size, the average cost per unit, including interest and depreciation at 10 per cent., varied from 0·40d. to 0·45d., rising up to as much as 0·5d. per unit, where the load was intermittent. He was satisfied that the only possible way to bring the advantages or otherwise of electric winding before the practical colliery owner or manager was to tell him at what cost he could wind coal per 100 tons with an electrical plant, leaving him, if he wished, to make his own calculations as to the winding-cost with steam; and if he could adopt the method of calculation as suggested in his (Mr. Mountain's) paper and utilize the same headings, he had no doubt that the colliery owner would be able to discover quickly whether electric winding would pay or not.

Table I., recording the actual cost of electrical winding-plants on the Continent, would be of interest. The plant included the winding-gears with motors, motor-generators and switchboards, but was entirely exclusive of the cost of generators.

TABLE I.—COSTS OF ELECTRIC WINDING-PLANTS ON THE CONTINENT.

Name of Mine.	Time of Coal-winding. Hours.	Depth of Shaft. Feet.	Coal wound per Day. Tons.	Cost of Electric Winding-gear. £
Zollern II. ...	8	990 to 1,650	1,350	10,000
De Wendel	8	2,640	1,400	15,000
Stinnes ...	8	1,500 to 2,600	800	10,000
Esperance ...	8	2,625	512	10,000
Grand Hornu	24	2,300	1,400	4,000

Mr. P. BARRETT COULSTON thought that sufficient facts had been elicited to satisfy those persons who had complained that they had had enough of general papers on electricity, and that facts were wanted. He thought that it had been shewn that Mr. Mountain's idea, that electricity could not be used for winding, was an isolated idea. Mr. Hooghwinkel had demonstrated that it could be so used, that it actually was so used at many collieries, and that it had the advantage in the matter of cost.

Mr. JOHN GERRARD (H.M. Inspector of Mines) exhibited several thermometers for taking the temperature of the strata in coal-mines.

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PART IX. VOL. XXIX.

TRANSACTIONS

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MANCHESTER GEOLOGICAL AND MINING SOCIETY.

ORDINARY MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
MAY 8TH, 1906.

MR. HENRY BRAMALL, PRESIDENT, IN THE CHAIR.

The following gentlemen were elected, having been previously nominated:—

MEMBER—

Mr. HENRY NEWMARCH ALLOTT, Assoc.M.Inst.C.E., 46, Brown Street, Manchester.

STUDENT—

Mr. JOHN SPENCER, Mining Student, 3, Major Street, Crawshawbooth, near Manchester.

Mr. WILLIAM WATTS read the following "Geological Notes on Sinking Langsett and Underbank Concrete-trenches in the Little Don Valley":—

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GEOLOGICAL NOTES ON SINKING LANGSETT AND UNDERBANK CONCRETE-TRENCHES IN THE LITTLE DON VALLEY.

By WILLIAM WATTS, Assoc.M.Inst.C.E., F.G.S.

The Langsett and Underbank trenches in the Little Don valley, near Penistone, were constructed in connection with the reservoirs for the Sheffield Corporation (Fig. 1, Plate XIV.).

Fig. 6.—Strata at the South End of the Langsett Trench.

Langsett Trench.—The sinking of the Langsett concrete-trench was commenced in September, 1897, and completed in July, 1899. It is 1,778 feet long, including the wing-gutter at the northern end, and the average depth is about 92 feet (Fig. 3, Plate XIV.). The middle of the trench was first excavated, so that the concrete refilling might begin at the deepest part of the

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valley. The ends were opened out as the embankment was raised, and the excavations were placed in it to form part of the permanent superstructure.

The geological section (Fig. 3, Plate XIV.), plotted to a natural scale, shews the depth and extent of the ground excavated. The width of the trench, from end to end, is 6 feet to within 20 feet of the surface, where the widening begins to form the shoulders for the puddle-wall. The measures lie fairly normal, and dip north-eastward at a slight angle. A number of open or slip-joints existed on the south side of the valley, but they disappeared as the trench was deepened and extended into the hill. They were crossed by other joints practically at right angles, and many of them were filled with impalpably fine ochreous mud. Mud-filled joints in shale are due to infiltrated matter from the surface, and are not channels through which water has been able to flow freely or they would be clean. Photographs were taken from time to time as the work proceeded; and these illustrate very clearly the changes in the ground as the measures were exposed (Figs. 6, 7, 8 and 9).

FIG. 7.—STRATA AT THE SOUTH END OF THE LANGSETT TRENCH.

The Rough Rock, of the Upper Millstone Grit series, is seen at both ends of the trench superposed on the shale in which the section was cut, and it forms the foundation of the impervious core of the embankment. This bed of rock had supplied stone of an excellent character for the various kinds of masonry required

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in the construction of the works. The texture is fine-grained, the lower beds are fairly massive, and, when the stone is carefully selected, the colour has a pleasing effect.

Large pockets of "red mare" or iron-stained material are frequently met with in quarrying, and it is interesting to know that the best-coloured stone is invariably found in proximity to these oxidized beds of irregular deposits. The leading backs or slip-joints are very pronounced, and often prove a great help in quarrying the rock, but they form undesirable lines of weakness in ground required for reservoir-purposes, in resisting the flow of water. The leading joints in rock are more open and longer than in shale, although apparently submitted to the same dis-

FIG. 8.—STRATA AT THE SOUTH END OF THE LANGSETT TRENCH.

turbing forces. Shale, therefore, forms a better watertight material for the foundation of a reservoir-embankment, and a bedded rock is more impervious than a massive rock: an interesting feature often noticed in this class of ground. A knowledge of the distinguishing features of the deposits helps the engineer in deciding how best to treat them, so as to render them absolutely impervious under severe hydrostatic pressure.

Near the middle of the trench (Fig. 3, Plate XIV.) and in the deepest part of the valley, some curiously contorted snake-like bands appeared in the strata, which were otherwise but little disturbed. They are composed of soft material, similar in nature to the ground on either side, and are caused by lateral pressure; and all traces of these foldings disappeared in the

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lowest part of the section, where it was deepened to run them out. It was not ascertained how far these ribbon-like contortions extended along the axis of the valley, but they proved impervious to water following the trend of them.

On the right hand side of the geological section (Fig. 3, Plate XIV.), a narrow fault, filled with compact clayey material, was intercepted heading to the north-east. It was also cut through in driving the discharge-tunnel; and, when tapped, a fierce rush of water caused the work to be suspended for several days, until it had unwatered the measures on the higher side. The flow did not cease during the time that the work was in progress, and it was conveyed away until it was sealed back by the main trench.

Fig. 9.—Contorted Strata in the Langsett Trench.

When the gutter was opened for its full length across the valley, the influx of water amounted to 1,250,000 gallons per day, and pumping had to be resorted to for many months in order to cope with it. The flow, however, was reduced during intervals of dry weather, but its regularity was strikingly maintained, providing a perennial supply, sufficient for a moderately large town. It was apparent from the outset that if the escape of water was to be prevented, when the additional weight of a full reservoir was added to the subterranean flow intercepted by the trench, excavations on a large scale would have to be undertaken.

There are few shales and rocks in the Pennine valleys which do not yield water when thoroughly opened out. The saturated

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ground in question was excavated only so far as it was required to make the embankment safe, to a point a few feet above the top water-level. To decide a problem of this nature makes demands upon the engineer of the severest kind, inasmuch as the success or failure of his work depends entirely upon his correct geological diagnosis as to how far the static and dynamic forces will affect the ground upon which so much money is being expended; and this, of course, cannot be tested until the reservoir is filled.

The author had been engaged in the sinking of many trenches for reservoir-embankments, but he had never found strata in which more water existed, under greater pressure, than in the Langsett shales, nor any which required more care and patience in getting to the bottom of them. An impervious foundation for a reservoir, 100 feet deep, requires very careful study of the conditions and a full knowledge of the consequences, in case of neglect or failure in the endeavour to secure it.

To test the hydrostatic head of water in the trench, a number of bore-holes were put down in which pipes were inserted, so that the effect of the subterranean water in finding its own level might be observed. It rose freely more than 20 feet above the floor of the open trench, when made ready for refilling. Two of the pipes were left permanently in the bore-holes, carried up to the surface-level and made to discharge into a strong drain under the outside base of the embankment, where the flow could be seen and measured for all time.

When a trench is bottomed, it should be immediately covered so as to prevent the floor from lifting in the centre. It is a common occurrence in shaly ground for the floor to lift, especially if kept open for some time before refilling. When it begins to rise, laminated beds sound "drummy," and, sometimes after long exposure, the effect is felt to a depth of 20 inches. It is assumed by geologists that "floor-creeping" is caused by the removal of the ground and atmospheric agencies, and to the weight of the two sides. It is doubtful, however, whether vertical side-pressure exerts much influence on the lifting tendency in wide and narrow trenches, excavated at varying angles to the dip of the beds. It has been asserted that the uplift or creep is due to hill-pressure, on either side of the valley, forcing the floor upward. If this suggestion be true, valley-strata should never cease from creeping and closing in.

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Many years ago, the author concluded that the Pennine buttresses were not at rest, and he is more and more confirmed in this opinion, the more his knowledge and experience are extended by the execution of large engineering works, in a number of valleys, during a period of more than 30 years. For many years he could not account for cracks occurring in masonry-walls built on rock-foundations, but not to the same extent in walls built on shale. The masonry requires to be of a high class to exhibit the cracks, and the walls to extend some distance on the hill-side, so as to cross a number of leading joints in the rocks. It is difficult to account for masonry-fractures cutting through solid stones, as well as widening the joints immediately over and under them, on any other hypothesis than that of ground-movement.

It would be of great scientific interest to discover whether the suggested force here alluded to has any connection with the folding of strata in the valleys, and with creeps in deep trenches and, sometimes, in tunnels.

Creeps and foldings of strata are not confined to valley-excavations alone. In driving the Strinesdale tunnel for the Corporation of Oldham, several foldings appeared in the floor, some time after the tunnel was opened, at a depth of 350 feet below the surface, and in the heart of the hill. The creep, however, in this case, was confined to shaly ground. The author has not noticed it in rock, beyond the upper or exposed beds occasionally getting drummy on exposure. In driving the Rivelin tunnel, for the city of Sheffield, creeps appeared in places to a height of 24 inches and seriously disturbed the side-trees and sleepers.

These examples furnish clear evidence of floor-lifting under hills, where the pressure is equal on both sides of the removed ground—favouring the idea that (when pressure is removed) the ground, in deep strata, rises from some cause or other, and, in the author's opinion, exposure and increased dampness have much to do with this rising.

With these general references to the Langsett trench it will be necessary only to speak of the geological features of the trench at Underbank, as the phenomena attending the sinking have already been described, and apply equally to both.

Underbank Trench.—The Underbank trench (Fig. 1, Plate XIV.) was opened across the Little Don valley about ½ mile

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higher up the river than the steel-works at Stocksbridge. The section (Fig. 5, Plate XIV.) is 1,782 feet long, with an average depth of 72 feet. The surface of the river-bed, at this point, is 550 feet above the Ordnance Survey datum-level, and the reservoir is constructed to supply compensation-water for the mill-owners.

The strata at the southern end rise very regularly, 1 in 8, from the fault to where the excavations terminate in impervious ground, a few feet above the top water-level of the reservoir (Fig. 5, Plate XIV.). The opening of the trench commenced on August 9th, 1901, and was completed in February, 1905. The ground was full of water under considerable pressure, as proved by a number of borings put down to test it. One of the borings discharged a copious flow of artesian water many feet above the bed of the river, and thus proved the soundness of the measures down-stream.

The fault near the northern end is a large one, and much wider at the top than at the bottom. It is filled with impervious rubbish from the sides, and the strata are much disturbed and crushed in its proximity. On both sides of the hade, the dip of the beds is fairly normal, but they incline more quickly on the north side. Two seams of coal and deposits of fire-clay enrich the ground. During the driving of the first Woodhead tunnel of the Great Central railway, these seams of coal were worked by bell-holes and adits to supply fuel for the motive power required in driving that long tunnel, which was commenced in 1838 and was completed in 1845.

Faults are regarded with serious misgiving by some hydraulic engineers, when met with in trenches designed for reservoir-embankments; but of the great number with which the author has had to deal, not one has proved a failure, or admitted a leakage. There are few deep trenches opened to a moderate length in the Pennine valleys without one or more faults appearing in them, and some of these may justly be regarded as beneficial and even act as auxiliary trenches. Where the hade-stuff is doubtful, it should be probed and followed; but, as a rule, faults are impervious to water.

The water derived from the coal-shales referred to was very ochreous, and stained the river-water for some distance below the adit-effluents. If these waters were collected and time allowed

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for precipitation and evaporation, it is possible that large stores of colouring matter could be obtained from them for use as a paint-mixture, and probably for other commercial purposes.

The coal and fire-clay here alluded to are denuded from the southern slopes of the valley on arriving at Midhopestones; but they repose under the hill on the northern side far away into north-west Yorkshire, so that in this respect the Little Don valley is a line of demarcation between the Lower Coal-measures and the Millstone Grits.

The rise of the ground on the south side of the valley is synchronous with the lie of the beds, whilst the outcropping

FIG. 10.—CONTORTED ROCK IN THE DISCHARGE-TUNNEL AT UNDERBANK.

strata on the north side present the irregular features of a broken landscape, but it is free from deep ravines and is fairly well wooded.

The discharge-tunnel through the embankment was excavated in solid rock from end to end. The floor of the invert, in many places, presented curved lines of fracture due, doubtless, in this case, to lateral pressure, as no other explanation seems feasible. Fig. 10 illustrates this phenomenon. The section is 22 feet wide and 18 feet deep, and was taken at the foot of the sloping

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ground, practically parallel with the strike, where one expects the greatest thrust to exist under the least valley-covering. The anticlinal part of the folded rock was quite "drummy," and lines of fracture ran along the ridge. The leading joints in this particular bed are not wide, but extend a long way before being cut off by others of minor importance. Several months after the completion of the lining of the tunnel, fine cracks appeared in the brickwork directly on the line of two of these leading joints, and the author attributed their formation to the opening of the main concrete trench, about 80 feet away. After the trench was refilled, the cracks in the lining alluded to were removed and no change has since been noticed; but it is doubtful whether they would have been thoroughly checked had the trench been refilled with puddle. Deep trenches, therefore, for reservoir-embankments should not be refilled with soft, yielding material, such as clay-puddle, in ground likely to be affected by the lateral thrust of strata weighted by high hills on one or both sides; especially when the strata dip at a fairly high angle into the cutting. Rock-movements are very slow, but their power is silent and great.

The power exerted by subterranean water occasionally displaces rock and shale, having merely a thin surface-covering. It is not the amount of water which does the mischief, but the great pressure slowly applied. In the tail-bay of the discharge-tunnel, referred to above, a layer of concrete 12 inches in thickness, overlaid with blocks of ashlar pitching 18 inches deep, was bodily lifted off the foundation on solid rock (several square feet in area) by the pent-up water, which did not appear at the surface when the works were in progress. While the building of the tail-bay was in hand, the concrete trench of the main embankment was being opened out at the same time; and this, no doubt, unwatered all the strata for some distance on either side. After the trench had been refilled, the subterranean water again found its way into the original ducts, which, in the meantime, had been covered by the masonry forming the pool at the tail-bay. Had the work been unsound and pervious, the sealed-in water would have found vents in it, and escaped unnoticed in the floor of the old river-bed. Three drill-holes bored into the rock, where the water asserted itself, sufficed to liberate and set it free to flow in a drain specially provided to receive it.

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Doubtless creeps are formed in this way, in some shales favourably placed for being raised, when relieved of the superimposed weight of the ground. The harder "plated shales" yield to the strain from below as readily as the more laminated and softer shales, but do not creep so high in the centre of the cutting.

In the lower reservoir-trench at Castleshaw, Saddleworth, owned by the Corporation of Oldham, and excavated in the Yoredale Shales, the confined water was interestingly responsive to pressure on a temporary plunger placed in any one of five boreholes, drilled in the approved bottom of the trench about 60 feet apart, to test the soundness of the ground to a greater depth than the eyes of the engineer had the power to see. When the plunger was briskly inserted in one of the holes, in which a 2 inches pipe had been inserted and made tight, water instantly rose up from the others like mimic fountains. Many curious traits are met with in underground water, which, at all times, is obedient to the laws of hydraulics and at the service of man. One can understand water being lowered to a common level in water-bearing rocks, but the transmission of hydrostatic pressure and hydraulic flow for some distance in compact shale is deeply interesting, especially when one finds that the thrust of a plunger is responded to at every beat by the rush of water out of the boreholes. In this respect, water proves itself a delicate conductor of force, and, under favourable circumstances, can be carried for long distances on all sides from the centre of action.

Glacial action does not appear to have played an important part in shaping the physical features of the lower slopes of the Little Don valley. There are no traces of ice-scoring, no boulder-clay, and no erratic blocks. All the clay in the valley is derived from disintegrated shale, it seldom exceeds 3 feet in depth, and rests beneath the soil some distance away from the river. In the flat of the valley, and elevated some 10 feet above the river-bed, both at Langsett and Underbank, innumerable subangular stones were discovered at the bottom of a thin deposit of yellow clay. Every stone is coated with a thin film of siliceous matter, as an exuberant growth after deposition. The filmy coating is equal in thickness on the larger and smaller stones

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alike, as if, during the centuries that have passed, some restraining influence had operated to equalize the deposit. The stones are not water-worn, as river-action wears them; and as the grit is not immediately local, the mind dwells on the theory that they were originally floated to their present position.

The richest soils in the valley lie on the verge of the river, and are thickest where the gradient is slight. This loamy deposit is left behind after floods, the valley-clays being above it in elevation and resting immediately upon the shales, which are often seen changing from shale into clay through infiltrations of water, the decaying action of vegetable substances, and changes in the temperature of the ground due to climatic conditions.

The geology of the Little Don valley presents a fairly regular sequence of strata on both sides, and one knows what to look for and where to find it. In this respect, it is good ground on which to construct earthen embankments for storing large volumes of water, and the material of which they have been made is as lasting as the surrounding hills.

The PRESIDENT (Mr. Henry Bramall), remarking that the members had heard a very interesting paper by Mr. Watts, who had brought before the Society many important facts, proposed that their thanks be given to Mr. Watts for his paper.

Mr. WILLIAM PICKSTONE seconded the motion, which was carried unanimously.

Mr. JESSE WALLWORK said that, in the case of the fault which was impervious to water, he assumed that there was some soft material lying between the two sides of the fault. He understood that the water did not find its way through the fault, and that Mr. Watts had no more difficulty in dealing with the water than in other parts. He was rather surprised at that, for in his experience in making small reservoirs, small compared with those mentioned by Mr. Watts, but large, perhaps, for a colliery, he had encountered difficulty in such cases.

Mr. HUGH M. CRANKSHAW said that he regarded Mr. Watts' statement about the water rising 20 feet through the pipe in the

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bore-hole, as proving the permanent saturation of the rocks at that level: therefore, the rocks must be permeable, and, if so, what guarantee had Mr. Watts that the hydrostatic pressure on the reservoir-side did not force water through them? He did not see why the water should not pass underneath the trench.

Mr. Charles Pilkington said that the fact of the water rising up the pipe to a height of 20 feet proved that the floor was water-tight, and, in making a reservoir, proof of that kind was wanted.

The President (Mr. Henry Bramall) said that Mr. Watts' description of the movements of the earth in the trenches reminded him of what one met with in coal-mines, and the causes of this "lifting" were the same in both cases. He did not think that they need consider the pressure from the surrounding hills. It seemed to him that the removal of the overlying earth in the trenches took away the vertical pressure that had been keeping down the lower beds in that portion, and set up what was known as the flow of solids; that is, the solid shale began to flow, and became puffed up, owing to the pressure of the sides, and this, he thought, was quite sufficient to account for the "drumminess." He was also interested in Mr. Watts' reference to the creep which took place over large tracts of strata when they were disturbed. When the lateral pressure of the strata was relieved by cutting on one side, the tendency, although the dip was not very severe, was for the beds to slide down to a lower level, and the puddle in the trench was, sometimes, squeezed to a serious extent. That, as Mr. Watts had said, was a striking phenomenon. They sometimes had something of the sort in a coal-mine: he remembered, on one occasion in a mine under his charge, that a large pillar of coal between two levels slipped down bodily from the rise side and closed the level road below.

Mr. William Watts said, with regard to the faults, that it might be taken for granted that all of them were refilled with material from either side of the hade. He had never seen them otherwise charged, and all that he had seen were as compact as they possibly could be, and impervious to water. Indeed, all the 18 reservoir-trenches that he had opened out had faults in them, and not one of them was leaking that day. With regard to the water rising in the bore-holes, it should be understood that, when the measures were thoroughly saturated, the water could

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not get away, and it was very possible that water did flow more freely along the bedding-planes of the shale than it could rise vertically through them. Indeed, it was always a pleasure to him to have a thoroughly wet trench rather than a dry one: in dry ground, the water was getting away somewhere, but when it could not escape the trench was water-tight, water-logged and water-bound. He thought that all deep trenches ought to be refilled with concrete, especially if the strata dipped on one side into the trench, for fear of the weight of the ground pushing through the soft puddle, which sometimes occurred. In making concrete, he (Mr. Watts) had used a great deal of Lias lime, which, for an impervious core, was as trustworthy as cement-concrete. When the trench was subjected only to the compressive strain, being wedged fast in solid ground, there was no lateral strain, and Lias-lime concrete was as impervious as cement-concrete, but it was longer in setting. In some cases, cement-concrete was used at the bottom of trenches and Lias lime at the top and broader part.

The crusher was regulated so as to break the stone as fine as possible, and to make sufficient sand. Some classes of stone produced much more sand than others, and a large quantity was got from rough Millstone Grit. The broken stone was taken out of the wagon as it came from the crusher. The cement and stone were mixed dry, and watered afterwards. Too much grout should not be used, as it introduced lines of weakness.

The cost per lineal yard for the whole width of the trench, in No. 1 section was £117 6s.; in No. 2 section, £105 1s. 1d.; and in No. 3 section, £131 14s. The disparity was accounted for by the fact that there was more excavation and costly timbering to provide in one case than in another. These comparative estimates were arrived at by comparing trenches driven 180 feet long and 60 feet deep in each of the three sections.

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MANCHESTER GEOLOGICAL AND MINING SOCIETY.

ORDINARY MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
JUNE 19TH, 1906.

MR. JOHN GERRARD, VICE-PRESIDENT, IN THE CHAIR.

THE LATE MR. C. E. DE RANCE.

The CHAIRMAN (Mr. John Gerrard) moved a resolution expressing sympathy with the representatives of the late Mr. De Rance, who was an honorary member of the society, a member of the Geological Survey for many years, and took an active interest in mining engineering and geological questions.

Mr. JOSEPH DICKINSON seconded the resolution, which was passed.

MARINE FOSSILS IN THE BANKS OF THE RIVER TAME.

Mr. JOHN GERRARD exhibited specimens of *Pterinopecten, Posidoniella sulcata, Orthoceras*, etc., from the marine-bed on the banks of the river Tame at Dukinfield. This bed was discovered by the late Prof. A. H. Green in 1860, and was connected with Ashton Moss colliery in 1880 by Mr. George Wild. The stratum is believed to be about 915 feet above the Roger mine.

Mr. WILLIAM WATTS read the following paper on "Alternative Schemes of pumping and supplying Water by Gravitation for the Use of Collieries":—

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ALTERNATIVE SCHEMES OF PUMPING AND SUPPLYING WATER BY GRAVITATION FOR THE USE OF COLLIERIES.

By WILLIAM WATTS, Assoc.M.Inst.C.E., F.G.S.

General Remarks.—It is difficult, if not impossible, for a water-works engineer to submit a general scheme of water-supply such as would suit the requirements and be applicable to the varying conditions under which the collieries in this country are worked or others which may be worked in the future.

In particular, he requires to know whether it is proposed to obtain the supply by gravitation or by pumping, the number of gallons required per day, and whether the water is to be exclusively used for trade-purposes or in part for domestic consumption. It is assumed that a total of 200,000 gallons per day is required at a colliery for the generation of steam and other processes, including coal-washing and general cleansing of the works, for which purposes water is not required to be of the pure quality needed for human consumption, and that this supply is readily obtainable in the immediate vicinity, possibly, by pumping from the pit-shaft.

As a rule, coal-pit shafts are sunk in the level parts of the country, where water is not obtainable near at hand from surface-sources.

In sinking shafts and wells, water is generally found within a reasonable distance below the surface, but the quality in many instances is not satisfactory for use in steam-boilers, owing to its ochreous character. Exposure to atmospheric agencies eliminates a large proportion of the ochre in solution, and forms a deposit which should find a market for use in the manufacture of paint. It would require, however, to be collected in a clean condition, and time should be allowed for evaporation and

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precipitation. For this purpose, a series of simple traversing channels are suggested (Figs. 1 and 2, Plate XV.). This design lends itself to easy manipulation in drawing off the water to collect the ochre, and also to the provision of long-distance pools on a small area of land: *a* is the water-inlet; *b*, wooden sluices; *c*, slots for the sluices; and *d*, the water-outlet.

Should the water require additional treatment after traversing these open channels, it could be passed on to a bed of clean cinder-ashes, and there is no reason why such a filter should not be made portable by placing the filtrate in vertical frames fixed in slots, attached to iron standards. The ashes are otherwise worthless at the pit, and the stock is daily increasing by the consumption of coal in providing steam for the winding-engines. This operation would be a process of straining rather than filtering, and simple and inexpensive frames only would be required.

In pit-sinking, as before stated, water is generally tapped within a reasonable distance below the surface, and if provision be made for collecting and storing it in underground receptacles, it is at all times available, close at hand; and a shortage is less likely to be felt than when dependence is placed upon precarious surface-feeders.

All subterranean water, however, has descended from the surface and is replenished by the rainfall; but its cone of drainage often extends a long way. Such a supply is beyond the influence of evaporation and surface-disturbances or the interference of the riparian owners. It is, therefore, less liable to be tampered with, as there are no invested rights to its use. It belongs to him who is willing to sink the deepest to obtain it.

With regard to surface-water supplies generally, conflicting claims are frequently made by neighbouring owners to the channels which have been formed by subaërial denudation, and thus induced the water to flow in paths, which the main physical features of the district do not appear to warrant, but they are, nevertheless, natural diversions from the original course. There are no joint owners of underground water, although sometimes ownership is claimed by the first person who may have sunk a well to obtain it. It certainly seems unfair that a man should have his well drained dry (after many years' use) by his neighbour who may sink a deeper well on adjoining land; but

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in cases where defined water-courses cannot be proved, the law affords neither protection nor redress.

Subterranean water, like atmospheric air and sunlight, is free to all and no one can interfere, or dictate, how deep a well or pit-shaft shall be sunk in order to obtain the natural products that they yield.

In considering a scheme for the provision of a water-supply by pumping, the above general remarks may not be considered out of place or uninteresting, especially where an alternative scheme of supply, by gravitation, is propounded.

Pumping Scheme.—Assuming that the quality of the water available in the strata opened up in a coalpit-shaft is satisfactory and sufficient in quantity, it is questionable whether it is not cheaper to pump it rather than to adopt a gravitation scheme involving greater cost of construction as regards the first outlay. The working expenses are greater in the former scheme, owing to the consumption of coal and incidental items, but when the extra cost of gravitation works is capitalized the initial cost may be in favour of a pumping scheme.

For water derived from geological strata, from which a perennial flow is available, very little storage-room is required at the surface; but some water must be stored so as to be available during breakdowns and other contingencies; probably a week's supply would be ample, though the working of each colliery would suggest its own demands. A small receptacle only is necessary underground to collect and pump from, and to meet the maximum demand during the working hours of the day, which may be in excess of the supply derived from ascertained subterranean feeders.

In a gravitation scheme, depending on a precarious supply at the surface, a month's stock is not too much to have in store at the commencement of a drought—unless all condensed water is returned into the reservoir.

Colliery engineers and managers need not be told what kind of pumping machinery is the best for their respective works. They have steam available at the pit, and can produce it more cheaply than firms having coal to buy, and haulage to pay for. Pneumatic pumping is simple and efficient, where it can be readily employed in forcing water from a lower to a higher level.

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The cost of pumping varies according to the class of pump introduced, the number of gallons to be raised and the height to which they must be lifted. Where large engines and pumps are in use, the average cost of forcing water to an elevation of 100 feet does not exceed 1d. per 6,000 gallons. Smaller supplies cost more, because the working expenses are greater *pro rata* to the number of gallons raised.

Gravitation Scheme.—Where a gravitation scheme, for the water-supply to a colliery, is adopted, it is of the utmost importance that a reliable source from which to draw should be secured. The obtaining of this important condition is often found to be extremely difficult and costly. The diversion of streams of water, together with the effluent from springs, often interferes with the rights which immemorial use has established, and arbitrary claims are sometimes set up and stoutly supported, by land-owners and others, when an attempt is made to appropriate them. The cost of land, particularly when its acquirement is opposed, is an important item; not only is this the case where land is required for sites for reservoirs, but also where wayleaves for the laying of pipes must be obtained. These difficulties do not arise where water can be obtained from the pit; the question then simply resolves itself into one of cost of installation of machinery, maintenance and the working expenses of pumping.

It has already been assumed that surface-water fails to flow in dry weather, thus rendering greater storage necessary, involving greater expense in construction, and the requirement of more land, with attendant cost and risks of legal entanglement, which is avoided where the water can be lifted from the colliery workings.

For the purpose of this paper it is assumed that a typical colliery requires, for all purposes, 200,000 gallons per day, and that 30 days storage should be provided to meet the requirements of a drought, necessitating a reservoir large enough to hold 6,000,000 gallons, requiring a space equal to 80 yards square by 5½ yards deep, or 35,200 cubic yards, allowing 168 gallons to the cubic yard.

Structural Design.—The physical features of the ground near the pit should determine the shape of the reservoir, and, if

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possible, a depression in the land should be chosen with an embankment at the lower end, in preference to "lined" slopes. The selection of a favourable site is an important factor in determining the cost of construction, although its situation may be some distance away from the point of consumption.

If storage-room has to be provided on fairly level and solid ground, no more excavation should be made than is necessary to raise an embankment, A, the requisite height to provide room for the number of gallons to be stored, and the slopes, G, should be made fairly flat, especially if "lined" with clay-puddle (Fig. 3, Plate XV.). It is wise to make the reservoir sufficiently deep to prevent the free growth of aquatic plants. All clay-lining, C, should have a coating of gravel, D, laid immediately upon it, in order to protect it from "wave-wash" under the pitching, E and F; and also to prevent the sun and dry winds from cracking the clay by evaporation, when the level of the water in the reservoir is lowered. If condensed water be returned to the reservoir, as previously suggested, the storage-capacity might be reduced somewhat and the growth of aquatic plants avoided.

The surface covered by water in a reservoir having the above capacity is $1\frac{1}{3}$ acres, but this does not include the area of the side slopes and land covered by the embankment, boundary walls, and other contingencies.

All valves and drawing-off apparatus should be fixed in a suitably designed and constructed valve-well, which will admit of their being easily worked and accessible for the purpose of cleaning and any necessary repairs.

Clay-puddle, C, is undoubtedly the most suitable material to use in the construction of shallow embankments built on land likely to subside, and when it is found on the site of the proposed work it is decidedly also the cheapest.

The author, however, sees no reason why burnt shale, cinder-ashes, and even hard raw shale, should not be used in lieu of puddle for lining colliery and other small reservoirs. The surface of the finished work could be cement-rendered or brick-faced in special cases. Indeed, this class of material could be used for many purposes below and above ground at a colliery. The author has successfully used cinder-ashes made into concrete for the side-walls for a filter-bed faced with bricks, set on

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edge; he has also built a stone-breaker pillar of similar material, which proved a complete success in the case of both works.* This class of concrete, herein alluded to and recommended, could be used for structural purposes in many works of secondary importance, as regards position and length of time likely to remain in use.

Clean ashes and broken shale in the proportion of 1 part of Portland cement to 5 parts by measure of the coarser aggregate would make a good concrete, if carefully mixed and placed in position in a jelly-like consistency. This material, however, is not recommended for resisting the compressive strain of heavy superstructures such as engine-bed and chimney-foundations; but for light foundations, and the wall-backing of minor buildings, it would answer admirably. To bear heavy weights, broken stone laid in successive layers of 3 inches, and grouted, makes a cheap and reliable foundation, and it may be further cheapened by the use of "plums" judiciously arranged; but it could not be guaranteed watertight, under considerable hydraulic pressure.

In "lined" reservoirs, springs rising in the ground are often a source of much trouble, especially where clay "lining" is used as an impervious sheeting, and unless they can be diverted or piped away the character of the puddle cannot be guaranteed against leakages. Many devices have to be resorted to in collect- them, so as to prevent the "lining" from being lifted, thus drawing on the experience and resources of the engineer to ensure success in this work.

In concrete-lined slopes, H (Fig. 4, Plate XV.), it is suggested that if shale and ashes be used as the impervious matrix, they should be cement-and-sand rendered, I, and brick-faced, J, above the top water-level, say, for a height of 2 feet. Rendering material, made of Portland cement and clean sharp sand, in the proportion of 2 parts to 1 part by measure, will not crack, if kept damp for several days, with frequently added sprays of water in dry weather; but it must not be rendered during a frost, and two thin coats should be applied. The author desired to emphasize the importance of sprinkling concrete with water,

* This stone-breaker, with jaws 20 inches by 10 inches, broke about 18,000 cubic yards of stone. The pillar was as firm, apparently, when it was pulled down as it was on the day it was put up. It was made entirely of ashes-concrete, because, at the time, stone was not obtainable.

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during the dry winds of summer and under the heat of the sun. Nothing disintegrates newly-made concrete sooner or more effectually than allowing it to become baked by the sun, or the water to evaporate out of it by dry winds. Water is absolutely essential to the crystallizing forces in concrete, without which it would not set, and it is a thousand times better to overdo it with water than to underdo it. An engineer, anxious to utilize the heat from some boilers, decided to cover the room over them with concrete. This concrete was mixed in the usual way, but the water was allowed to evaporate quickly and the matrix in a very short time was absolutely useless. It began to disintegrate, crumble away and it had to be removed. The room over the boilers was recovered with concrete; and, on the suggestion of the writer, it was watered every day for a period of three weeks. The concrete set in due course and, at the present time, is still fulfilling the intended purpose. A brick-facing may be used in lieu of the rendering, but great care is required in mortaring all the beds and joints.

Costs.—An estimate of the cost of the several works suggested in this paper cannot be given in the absence of fuller information, as much depends on the nature of the ground, the distance that the material has to be conveyed or hauled, and the permanency and finish required in the work.

The excavations may vary in cost from 10d. to 1s. 6d. per cubic yard. Puddle costs from 4s. to 7s. per cubic yard. Concrete in broken stone, in the proportion of 5 parts to 1 part of cement, costs 18s. to £1 2s. per cubic yard of finished work; but cinder-ashes, shale and coarse gravel mixed would cost much less. Much depends on the quality of the material and work in estimating what the cost will be, as also the experience of the men engaged in executing it.

These form the chief items of cost in the class of work alluded to by the author. Small reservoirs cannot be made so cheaply per 1,000 gallons of storage as larger ones.

Cooling Ponds.—The author suggests in Figs. 1 and 2 (Plate XV.) a method of cooling water, and eliminating, by precipitation, the ochreous constituents sometimes found in it when pumped from colliery-workings. It does not require to

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be explained how the ochre may be removed from the channels for use. By a simple arrangement of wooden sluices or "shuttles," *b* (Fig. 1, Plate XV.), the flow may be divided and diverted at a trifling cost.

Discharge of Water from Pipes.—The table of the discharge of water from cast-iron pipes (Appendix) may prove useful, as a ready means of ascertaining the delivering capacity of pipes under the heads and distances named under the respective headings. The formula will enable calculations to be made, and the usefulness of the table may be extended to larger pipes and longer distances as required. The examples worked out are sufficiently numerous and so simple as to be understood without further explanations.

Conclusion.—Upon the respective merits of the two schemes submitted for the supply of water to collieries, namely, (*a*) pumping or (*b*) gravitation, the author does not assume to decide in the absence of fuller information. Special advantages in favour of one or the other will arise in particular cases, and, in the absence of details, the colliery-owner must be left to judge which of the two schemes is most suitable for his own special requirements.

APPENDIX.

TABLE OF THE DISCHARGE OF WATER THROUGH PIPES 15, 12, 9, 6, 4, 3 AND 2 INCHES IN DIAMETER, UNDER DIFFERENT PRESSURES, AND AT DIFFERENT DISTANCES FROM THE SOURCE.

The following formula has been used in the calculation of the table:— $v = \sqrt{\frac{2{,}500DH}{L+50D}}$. D is the diameter of the pipe in feet; H, the head or pressure of the water in feet; L, the length of the pipe in feet; and v, the velocity of the water in feet per second. A cubic foot of water has been taken as equal to 6·23 gallons.

Pressure or Head.	Diameter of Pipe.	Volume of Water per Hour.					
		Distance from Source.					
		100 Yards.	250 Yards.	500 Yards.	750 Yards.	1,000 Yards.	1,500 Yards.
Feet.	Inches.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.
20	15	361,399	241,395	174,073	143,087	124,338	101,868
,,	12	210,538	139,258	100,046	82,130	71,321	58,393
,,	9	104,444	68,374	48,934	40,118	34,815	28,485
,,	6	38,623	25,012	17,830	14,598	12,659	10,351
,,	4	14,184	9,119	6,484	5,303	4,597	3,757

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TABLE OF THE DISCHARGE OF WATER, ETC. (*continued*).

Pressure or Head.	Diameter of Pipe.	Volume of Water per Hour. Distance from Source.					
		100 Yards.	250 Yards.	500 Yards.	750 Yards.	1,000 Yards.	1,500 Yards.
Feet.	Inches.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons
20	3	6,963	4,457	3,165	2,587	2,242	1,832
,,	2	2,541	1,620	1,149	939	813	654
40	15	511,095	341,384	246,176	202,355	175,840	144,063
,,	12	297,746	196,941	141,486	116,149	100,863	82,580
,,	9	147,705	96,696	69,203	56,735	49,235	40,283
,,	6	54,621	35,372	25,216	20,645	17,904	14,639
,,	4	20,062	12,896	9,169	7,500	6,501	5,313
,,	3	9,845	6,350	4,476	3,659	3,171	2,591
,,	2	3,593	2,292	1,625	1,328	1,150	940
60	15	625,961	418,109	301,503	247,828	215,359	176,441
,,	12	364,663	241,202	173,285	142,253	123,531	101,140
,,	9	180,902	118,428	84,756	69,486	60,301	49,337
,,	6	66,897	43,321	30,883	25,285	21,927	17,928
,,	4	24,576	15,792	11,230	9,186	7,962	6,506
,,	3	12,060	7,721	5,482	4,482	3,884	3,173
,,	2	4,402	2,807	1,990	1,626	1,409	1,151
80	15	722,797	482,790	348,145	286,174	248,675	203,737
,,	12	421,077	278,516	200,092	164,260	142,641	116,786
,,	9	208,887	136,746	97,868	80,236	69.629	56,969
,,	6	77,246	50,023	35,660	29,196	25,320	20,702
,,	4	28,378	18,238	12,967	10,607	9,194	7,513
,,	3	13,926	8,915	6,330	5,175	4,485	3,664
,,	2	5,083	3,241	2,298	1,878	1,627	1,329
100	15	808,112	539,776	389,238	319,952	278,027	227,784
,,	12	470,778	311,391	223,710	183,648	159,478	130,570
,,	9	233,543	152,889	109,420	89,706	77,848	63,694
,,	6	86,364	55,927	39,869	32,642	28,308	23,145
,,	4	31,728	20,391	14,498	11,859	10,279	8,400
,,	3	15,572	9,967	7,077	5,786	5,014	4,097
,,	2	5,683	3,624	2,569	2,100	1,819	1,486
150	15	989,731	661,087	476,717	391,860	340,513	278,978
,,	12	576,583	381,374	273,987	224,922	195,320	159,915
,,	9	286,031	187,251	134,012	109,868	95,344	78,009
,,	6	105,774	68,497	48,830	39,979	34,670	28,347
,,	4	38,858	24,974	17,756	14,524	12,589	10,288
,,	3	19,069	12,204	8,668	7,087	6,141	5,018
,,	2	6,961	4,438	3,147	2,570	2,228	1,820
200	15	1,142,840	763,359	550,466	452,480	393,190	322,136
,,	12	665,781	440,373	309,172	259,718	225,536	184,654
,,	9	330,280	216,219	154,743	126,864	110,093	90,077
,,	6	122,137	79,093	56,384	46,164	40,034	32,733
,,	4	44,870	28,837	20,503	16,771	14,537	11,880
,,	3	22,019	14,096	10,008	8,183	7,091	5,794
,,	2	8,037	5,125	3,634	2,969	2,573	2,101
250	15	1,277,740	853,461	615,440	505,889	429,593	360,159
,,	12	744,366	492,352	353,716	290,373	252,156	206,450
,,	9	369,264	241,740	173,008	141,838	123,088	100,708
,,	6	136,554	88,429	63,039	51,612	44,759	36,596
,,	4	50,168	32,241	22,923	18,751	16,253	13,281
,,	3	24,618	15,760	11,190	9,149	7,929	6,478
,,	2	8,956	5,730	4,062	3,320	2,876	2,350

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The CHAIRMAN (Mr. John Gerrard) said that the members were very much indebted to Mr. Watts for again favouring them with a paper out of his large experience and technical knowledge of water-works and water-storage. He was quite sure that the information which Mr. Watts had given them in his paper might be thoroughly relied upon, and he had the greatest possible pleasure in moving a vote of thanks to Mr. Watts for his interesting and valuable paper.

Prof. W. BOYD DAWKINS, in seconding the resolution, said that Mr. Watts had told the members of the means by which reservoirs might be made watertight. He (Prof. Dawkins) had found the application of common ashes to be the simplest and most effective means of stopping a leak in the case of a reservoir where the water-pressure was not very great. Many years ago his attention was drawn to this method by the late Mr. Thomas Hawksley. Shortly afterwards, he (Prof. Dawkins) was with a friend who had a large ornamental pond that leaked, and this leak was stopped with a few barrowfuls of ashes. In another case at Whitestaunton Manor, Somersetshire, the water came freely through the bank and the side. The bank was about 300 feet long, and the application of two wagon-loads of ashes was sufficient to raise the water in two days upwards of 2 feet; and from that day, the bank had been perfectly serviceable and watertight. In a third case, at Plas-yn-Cefn, near St. Asaph, the same remedy was applied to a leaky bank made of concrete, the concrete having cracked. Here again, the ashes stopped the leak. He (Prof. Dawkins) did not think that it would be desirable to apply this remedy to large reservoirs, but he thought that anyone might make small reservoirs or small tanks watertight in this simple way.

The resolution was passed.

Mr. W. PICKSTONE said that he had cured a leaky bank, over fifty years ago, in the way suggested by Prof. Boyd Dawkins.

Mr. W. OLLERENSHAW said that colliery-managers like himself, who had not received the training of a civil engineer, had been thus furnished with some very valuable information, which would be of great assistance in providing and storing the water required for use at collieries. He (Mr. Ollerenshaw) had that day tapped a large accumulation of water by boring through some dams, and the formula and table attached to Mr. Watts' paper

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would assist him in determining the size of pipe necessary to conduct the water to the pump, which had been put down to unwater the mines. He asked at what depth of water would the growth of aquatic plants be prevented.

Mr. W. PICKSTONE said that at a colliery which was stopped, the water rose in the shafts to its natural level; and at certain seasons of the year the water pumped from that colliery, to an adjoining reservoir, became full of aquatic plants. These disappeared when the weather changed, but they resulted apparently from the pumping of water from the colliery-workings. He would like to ask Mr. Watts whether he had met with anything of that kind, as the result of water pumped from colliery-workings.

Mr. SYDNEY A. SMITH asked for further information as to the statement that "where large engines and pumps are in use, the average cost of forcing water to an elevation of 100 feet does not exceed 1d. per 6,000 gallons."* He thought that the cost was too small, as it would only give 2s. a day as the cost of pumping 6,000 gallons per hour; and the cost of pumping 18,000 gallons per hour from a depth of 150 feet would only be 9s. per day. He (Mr. Smith) did not think it possible to pump the water for anything like that cost. Could Mr. Watts state what was a fair annual allowance to make for evaporation over very large areas, say, over the whole gathering ground, and also over the area of the reservoir? With regard to embankments likely to subside, could Mr. Watts give the members any results of his experience as to embankments which had subsided, and the course that he would adopt in a colliery-district when building an embankment of that kind? Mr. Watts said that "clean ashes and broken shale in the proportion of 1 part of Portland cement to 5 parts by measure of the coarser aggregate would make a good concrete, if carefully mixed and placed in position in a jelly-like consistency."† He asked whether that would be a watertight substance? With regard to "the use of 'plums,' judiciously arranged,"‡ he asked the proportion that Mr. Watts would suggest putting into concrete under such circumstances. Mr. Watts also referred to the trouble caused in "lined" reservoirs by "springs rising in the ground,"§ and he would be glad if Mr. Watts would enlarge upon that important

* *Trans. Inst. M. G. M. S.*, 1906, vol. xxix., page 457.

† *Ibid.*, page 459. ‡ *Ibid.*, page 459. § *Ibid.*, page 459.

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point. He also asked Mr. Watts to tell the members something about his experience of subsidences where water had got under the embankment; and what had been the effect on an embankment of rubble ground. Mr. Watts stated that "rendering material, made of Portland cement and clean sharp sand, in the proportion of 2 parts to 1 part by measure, will not crack, if kept damp for several days, with frequently added sprays of water in dry weather; but it must not be rendered during a frost, and two thin coats should be applied."* What thickness of lining would Mr. Watts recommend?

Mr. Vincent Bramall instanced the case of a reservoir on a water-logged peat-bed. When the water rose on the land around the reservoir and the water in the reservoir was low, the water, escaping from the peat, lifted up the puddle-bottom of the reservoir and caused it to leak. It was cured by placing another layer of puddle, about 1 foot thick, over the bottom, and there had been no leakage since.

Mr. H. Stanley Atherton asked whether Mr. Watts had had any experience in the use of bitumen-sheeting as a surface-lining. He thought that it would help to make a cheap and serviceable reservoir, when concrete was not available.

Mr. William Watts, replying to the discussion, said that the depth of the growth of aquatic plants depended on the source of the water. Water flowing slowly from the surface was much warmer, and brought with it food for the plants in a reservoir; whereas a small reservoir, fed with water from a spring, was not so likely to induce the growth of aquatic plants for the want of supporting material. He did not think that plants would do much harm growing deeper than about 8 or 10 feet; and without root-hold they became a floating growth. The cost of pumping, 1d. per 6,000 gallons per hour, was taken from Mr. William Humber's *Comprehensive Treatise on the Water-supply of Cities and Towns*.† Evaporation varied very considerably, and it was, of course, greater on the surface of water than on the surface of land. On a hot day, the evaporation would be very considerable, and probably would not fall short of 1 inch; but that depth or rate did not take place daily all the year round. It was usual, in making calculations for the supply of a city or town with water, to

* *Trans. Inst. M. G. M. S.*, 1906, vol. xxix., page 459. † London, 1876, page 161.

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allow 14 inches from the rainfall of the drainage-area for evaporation. On a drainage-area composed of permeable strata, receiving the rain as it came, the evaporation was very small; but, in a flat district like the Thames valley, the evaporation would be 14 or 16 inches per annum. Puddle required about 20 or 25 per cent. of water to make it plastic; but a good deal depended on the nature of the material. Before clay could be made into puddle, the water must be squeezed out of it. He had found satisfactory results in the case of a trench, over 100 feet in depth, which had settled over 4½ feet, and there was no sign of weakness. With regard to the use of "plums," one could put in as many as one wished, but never two together. It was well to fix them in a triangular form, and there must, of course, be enough fine concrete to fill in the interspaces. In narrow trenches, he (Mr. Watts) did not use plums; but in wider parts he recommended them. It was possible to economize too much in that direction, and it was necessary to be careful when great pressure had to be dealt with. Water getting below the puddle was extremely objectionable, and the method of stopping up a spring by covering it over with clay was a risky business. He (Mr. Watts) was aware that if a greater weight of impervious material were put on a lesser weight, the water would be checked for the time being, but it was persistent, unmerciful, and ever working; and instead of choking a spring with clay, he would run the water away in pipes.

He (Mr. Watts) did not advocate the use of lined embankments, because of the danger of water either getting at the back from the surface, or piercing the puddle; and, when the reservoir was drawn down, bursting and pushing it out, and causing slips. The trend of his (Mr. Watts') remarks had been in favour of the use of a concrete-lining rather than of a puddle-lining, for when water acted on puddle it was sure to carry it away sooner or later. With regard to bituminous sheeting, he had no sympathy with engineers who timidly used it to make their concrete watertight. The tendency with many engineers was to introduce bituminous sheeting in the concrete, in order to make it watertight. This method was adopted in filter-beds and clear-water tanks, from 3 to 12 feet in depth. It made a sandwich of a bituminous film, which ought not to be there, as it acted as a line of weakness in the work.

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MANCHESTER GEOLOGICAL AND MINING SOCIETY AND NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

EXCURSION MEETING,
HELD AT HULTON, BOLTON, JULY 30TH, 1906.

HULTON COLLIERY COMPANY, LIMITED.

ATHERTON, NOS. 3 AND 4 PITS.

Winding-engines.—The No. 3 pit winding-engine, with two cylinders, each 32 inches in diameter, and a cylindrical drum 15 feet in diameter, is winding from the depth of 900 feet. The No. 4 pit winding-engine, with two cylinders 36 inches in diameter and a cylindrical drum 18 feet in diameter, is winding from two different mines at depths of 450 feet and 1,320 feet respectively. Both engines are controlled by foot- and steam-brakes, and the ropes are fitted with Ormerod safety detaching-hooks.

Boilers.—There are eight boilers, four working at a pressure of 100 pounds per square inch, and four at 150 pounds per square inch. The low-pressure boilers supply steam to the winding-engines, while the high-pressure boilers supply steam to the electric generators. The high-pressure boilers are fitted up with forced-draught apparatus. The boilers are fed through economizers, by means of electrically-driven three-throw pumps, one being of the variable-stroke type. A steam-pump is kept as a stand-bye.

Electric Plant.—The power-house, placed midway between the two pits, has two stories: the upper being the engine-room, and the lower is divided into an electrical-fitting shop, repair-shop, condenser-room and transformer-chamber.

The engine-room contains three Parsons three-phase condensing turbo-alternators; one alternator is of 350 kilowatts and two of 300 kilowatts normal capacity at 465 volts, and they are

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capable of standing 25 per cent. of overload for 2 hours, and run at 3,000 revolutions per minute. The circulating water for the condensers, of the ejector-type, is supplied by two motor-driven centrifugal pumps.

These generators supply power for the whole of the work at the Nos. 3 and 4 pits, with the exception of winding, and for a considerable portion of the work at the Chequerbent and Atherton No. 1 pits. The power is conveyed to the latter by means of an overhead transmission-line, about 1¼ miles long, the pressure being raised at the power-house to 3,300 volts. At Chequerbent pits, the current is applied, without stepping down, to a ventilating fan, driven by a motor of 150 horsepower and to two motors of 125 horsepower, driving direct-current generators.

The large switchboard in the power-house controls the supply of power to the Nos. 3 and 4 pits, and the small one, the high-voltage transmission-line.

Three transformers, situated on the lower floor, are each of 120 kilowatts capacity.

Electric driving is applied to ventilating, screening, pumping, hauling, coal-cutting, boiler-feeding, forced draught, sawing, air-compressing, briquette-making, and other purposes. There is also an extensive lighting installation.

Banking and Screening.—The cages are of the two-decked type, holding three tubs on each deck. The tubs on leaving the cage gravitate to a creeper-chain, which conveys them to the weighing-machine at a higher level.

The tipplers are mechanically driven, and the screening is done by means of shakers. The empty tubs from the tipplers gravitate round a curve to a creeper-chain, which raises them to a higher level, whence they gravitate to the back of the pit. The picking-belts are made of wire-webbing, and the coal is lowered into the wagons by means of mechanically-controlled lowering arms. The small sizes of coal are stored in bunkers, from which the coal is run into wagons by means of trap-doors, as required.

Railway-sidings.—The railway-sidings lead under the screens, and thence to the wagon weighing-machine, and a diversion from the main-line leads to the briquette-siding and briquette-house.

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The sidings are so laid that the railway-wagons gravitate gently to the various points of call, and pass away again when liberated. The services of the locomotive are not required from the beginning of this operation until the wagons have been filled, weighed, and placed in the sidings.

Shafts.—There are two shafts, and coal is at present being wound from three mouthings:—The Trencherbone mine, at a depth of 450 feet; the Yard mine, at a depth of 900 feet; and the Arley mine, at a depth of 1,320 feet.

All the underground roadways have been laid out with a view to facilitate the quick handling of coal.

The Trencherbone mine is equipped with an electrical hauling-engine of the endless-rope type. The mine is ventilated by an underground Sirocco fan, 30 inches in diameter, rope-driven by an electric motor of 30 horsepower, producing about 20,000 cubic feet of air per minute at 1 inch of water-gauge.* There are two large three-throw pumps driven by an electric motor: one, near the pit, pumping about 10,000 gallons of water per hour. A Hurd coal-cutter is working in this mine.

The Yard mine is equipped with an electric hauling-engine of the endless-rope type. It is ventilated by an underground Sirocco fan, 45 inches in diameter, rope-driven by an electric motor of 45 horsepower, and producing about 50,000 cubic feet of air per minute at $1\frac{3}{4}$ inches of water-gauge.

The Arley mine is equipped with an electric hauling-engine of the endless-rope type. It is ventilated by an underground Sirocco fan, 45 inches in diameter, rope-driven by an electric motor of 45 horsepower, and producing about 50,000 cubic feet of air per minute at $1\frac{1}{2}$ inches of water-gauge. A Diamond disc three-phase coal-cutter is working in this mine.

The Three-Quarters mine, reached by a tunnel from the Arley mine, is fitted with an electrically-driven Ingersoll-Sergeant air-compressor, driving a heading-machine of the percussive type.

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* "Underground Fans as Main Ventilators," by Mr. Alfred J. Tonge, *Trans. M. G. M. S.* 1906, vol. xxix., page 407.

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The entire Series of the Geological Survey Maps on the one-inch and six-inch scale, with Memoirs, of the Lancashire Coal Field, is now complete, and available for reference by the Members.

Catalogue of the Library, price 1s. 6d.

Mr. Dickinson's Chart of Coal Strata of South Lancashire may be had separately at 6d., or with the part containing the letterpress at 1s. each.

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This Part concludes the Volume.

PART X. VOL. XXIX.

TRANSACTIONS

OF THE

MANCHESTER GEOLOGICAL & MINING SOCIETY.

EDITED BY

THE HONORARY SECRETARY.

SESSION 1906-1907.

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(Federated with the Institution of Mining Engineers.)

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(*d*) Indicates Members Deceased.

Year of Election.	Names and Addresses.
	HONORARY MEMBERS.
1874	Agassiz, Alexander, Cambridge, Massachussetts, U.S.A.
1891	Bell, Thomas, J.P., 15, The Valley, Scarborough.
1904	Bolton, Herbert, F.R.S.E., The Museum, Bristol.
1877	Broeck, Ernest Van den, 32, Place de l'Industrie, Brussels.
1877	(*d*) De Rance, C. E., F.G.S., 32, Carshalton Road, Blackpool.
1874	Geikie, Sir Archibald, D.Sc., LL.D., F.R.S., 3, Sloane Court, London, S.W.
1874	Hull, Professor Edward, M.A., F.R.S., 14, Stanley Gardens, Notting Hill, London, W.
1879	Kinahan, G. H., M.R.I.A., Woodlands, Fairview, Co. Dublin.
1873	Martin, Joseph S., I.S.O., H.M. Inspector of Mines, The Vikings, 16, Durdham Park, Clifton, Bristol.
1905	Saint, William, H.M. Inspector of Mines, Kersal Bank, Higher Broughton, Manchester. *Past-President.*
1880	Stirrup, Mark, F.G.S., High Thorn, Stamford Road, Bowdon, Cheshire. *Past-President.*
1890	Whitaker, William, B.A., F.R.S., F.G.S., Freda, Campden Road, Croydon.
	MEMBERS.—FEDERATED.†
	M.INST.M.E.
1906	Allott, Henry Newmarch, Assoc.M.Inst.C.E., 46, Brown Street, Manchester.
1893	Ashworth, John, C.E., 8, King Street, Manchester, *Vice-President.*
1878	Ashworth, Thomas, Kenmal Wood, Chiselhurst, Kent.
1895	Atherton, H. Stanley, Heath Cottage, Sharples, Bolton. *Member of Council.*
1877	Atherton, James, 13, Mawdsley Street, Bolton.

† For List of non-Federated Members see page xiv.

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Year of Election.	Names and Addresses.
1897	Baker, Godfrey, 457, Bolton Road, Pendlebury, near Manchester.
1901	Baldwin, Walter, F.G.S., Townhead, Rochdale.
1875	Barrett, W. S., J.P., 64, The Albany, Old Hall Street, Liverpool. *Past-President.*
1904	Bastow, S. E., Messrs. Bruce Peebles & Co., Ltd., East Picton, Edinburgh.
1903	Bentley, George, Pendleton Colliery, Pendleton, Manchester.
1898	Boden, Peter, 27, Albert Street, Milnrow, Rochdale.
1889	Bolton, Edgar O., Burnley Collieries, Burnley.
1880	Bolton, H. H., High Brake, Accrington.
1902	Bouchier, C. F., Strangeways House, Platt Bridge, Wigan. *Member of Council.*
1904	Bradshaw, Hubert, Stoneclough, near Manchester.
1886	Bramall, Henry, M.Inst.C.E., Pendlebury Collieries, Pendlebury, Manchester. *President.*
1904	Bramall, Vincent, Pendlebury Colleries, Pendlebury. *Member of Council.*
1902	Brewerton, Joseph, 97, Bridge Street, Manchester.
1904	Buckley, Charles Arthur, The Thorns, Prestwich Park, Manchester.
1878	Burrows, John S., F.G.S., Green Hall, Atherton, near Manchester. *Past-President.*
1887	(*d*) Campbell, W. M., Sutton Heath Colleries, St. Helens, Lancashire.
1904	Carter, J., Rainford Colleries, Rainford, St. Helens.
1904	Cass, J., 568, Liverpool Road, Platt Bridge, Wigan.
1901	Chapman, C. H., 293, Liverpool Road, Salford.
1898	Clark, Robert F., Bickershaw Collieries, Leigh, Lancashire.
1903	Clark, William, Garswood Coal and Iron Co., Park Lane, Wigan.
1894	Clarke, Robert, 42, Deansgate, Manchester.
1901	Coleman, W. H., 78, Egerton Road, Withington, Manchester.
1904	Constantine, E. G., Stirling Boiler Co., Motherwell, N.B.
1901	Cotterill, H. W. B., Hazlehead, near Sheffield.
1905	Coulston, P. Barrett, 5, Cross Street, Manchester.

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Year of Election.	Names and Addresses.
1878	Cowburn, Henry, 253, Westleigh Lane, Westleigh, Manchester.
1883	Crankshaw, Joseph, F.G.S., 11, Ironmonger Lane, London.
1905	Dawes, Alfred, Llithfaen, Pwllheli, North Wales.
1869	Dawkins, Professor W. Boyd, M.A., D.Sc., F.R.S., F.G.S., F.S.A., Assoc.Inst.C.E., Fallowfield House, Fallowfield, Manchester. *Past-President.*
1900	Deane, Adam, Stopes Colliery, Little Lever, Bolton.
1903	Dickson, James, Westhoughton Collieries, near Bolton.
1903	Dixon, Walter, Birkacre Collieries, Coppull, near Chorley.
1904	Dixon, William B., Coalbrook Vale Colliery, Nantyglo, Mon., R.S.O.
1889	Dobbs, Joseph, Coolbawn House, Castlecomer, Co. Kilkenny.
1898	Douglas, Ernest, Pemberton Collieries, Wigan.
1898	Eagle, George, 37, Brown Street, Manchester.
1905	Eames, Cecil W., Moss Hall Collieries, Platt Bridge, Wigan.
1903	Edmondson, R. H., Garswood Hall Collieries, Wigan.
1884	Elce, George, Rock Mount, Altham, Accrington.
1878	Ellesmere, the Right Hon. the Earl of, Worsley, near Manchester.
1897	Ellis, W. T. Wood, 34, Strand, London, W.C.
1895	Ellis, Thomas Ratcliffe, King Street, Wigan.
1895	Evans, Robert, Olive Bank, Royton, Oldham.
1897	Evans, Walter, J.P., Royton, Oldham.
1880	Fairclough, William, F.S.I., Leigh, near Manchester.
1891	Finch, John, Milfordholm, Victoria Road, Sutton Coldfield.
1891	Fletcher, Arthur, 8, St. Andrews, Ainsworth Road, Radcliffe, near Manchester.
1896	Fletcher, Leonard R., Atherton Collieries, Atherton, near Manchester.
1868	Fletcher, Thomas, Wheatfield, Bolton.

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Year of Election.	Names and Addresses.
1904	Gamlen, Robert Lorraine, 196, Deansgate, Manchester.
1873	Garforth, W. E., M.Inst.C.E., F.G.S., Snydale Hall, Pontefract.
1893	Garside, Edward, B.Sc., Assoc.M.Inst.C.E., Town Hall Chambers, Ashton-under-Lyne.
1902	Garton, Walter T., F.G.S., C.E., Brookfield, Wigan Road, Ashton-in-Makerfield.
1892	Gerrard, John, H.M. Inspector of Mines, Worsley, near Manchester. *Past-President.*
1898	Glover, J. W., Hall Street, St. Helens.
1903	Glover, Robert B., c/o Glover Bros., Hall Street, St. Helens, Lancashire.
1905	Grave, J. U. Roger, 58, Woodbine Terrace, Pinderfield Road, Wakefield.
1904	Grant, Ronald Gordon, 5, Great George Street, London, S.W.
1903	Graham, George, Sylvan Avenue, Brooklands, Cheshire.
1882	Greenhalgh, Robert, Engineer, Atherton, near Manchester.
1874	Greenwell, G. C., M.Inst.C.E., F.G.S., Beechfield, Poynton, Cheshire. *Past-President.*
1879	Greenwood, John, 1, Marsden Street, Manchester.
1877	Grundy, H. Taylor, Blackburn Street, Radcliffe.
1888	Grundy, James, H.M. Inspector of Mines in India, F.G.S., 5, Middle Road, Calcutta, India.
1877	Harris, George E., Assam Railway and Trading Co., Limited, Margerita, Assam, India.
1904	Harris, H. P., Brynn Dedwydd, Wrexham.
1894	Harrison, George B., H.M. Inspector of Mines, Worsley Road, Swinton, Manchester. *Vice-President.*
1906	Hart-Davies, Capt. Henry Vaughan, Wardley Hall, Worsley, near Manchester.
1905	Harvey, R. H., Anchor Cable Co., Leigh, Lancashire.
1889	Higson, Charles H., The Chestnuts, Helsby, via Warrington.
1904	Higson, Peter, 18, Booth Street, Manchester.
1904	Hodge, W. Guy, Star Life Buildings, 30, Cross Street, Manchester.

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Year of Election.	Names and Addresses.
1878	Hollingworth, Col. George H., F.G.S., 37, Cross Street, Manchester. *Past-President. Hon. Treasurer.*
1904	Hollingworth, F. H., The Oak, Hollinwood, Oldham.
1903	Hollingworth, Henry, Ellerbeck Colliery, Coppull, Chorley.
1904	Hooghwinkel, Gerald H. J., Dacre House, Victoria Street, London, S.W.
1906	Hopkinson, Austin, A.M.I.Mech.E., A.M.I.E.E., 86, Cross Street, Manchester.
1906	Houghton, Henry, Oak Mount, Ormskirk Road, Skelmersdale, Lancashire.
1905	Horrobin, William, Bedford Collieries, Leigh, Lancashire.
1894	Hughes, Owen, Haidman House, Hollinwood, Oldham.
1903	Humphris, Henry, Blaenau Festiniog.
1884	Jobling, John, Cliviger Collieries, Burnley.
1882	Johnson, William, Sidi Alowe, El Biar, Algiers.
1903	Johnson, W. H., B.Sc., Woodleigh, Altrincham, Cheshire.
1903	Jones, O. R., H.M. Inspector of Mines, 5, Spring Gardens, Chester.
1905	Kay, Joseph, Agecroft Colliery, near Manchester.
1897	Keen, James, Hindley Green, Wigan.
1905	Kneebone, C. Maitland, Oakdale, Grove Park West, Colwyn Bay.
1887	*Knowles, Lt.-Col. Sir Lees, Bart., M.A., LL.M., F.G.S., D.L., Westwood, Pendlebury. *Trustee.*
1904	Knowles, R. E., Furness Vale Fireclay Works, near Stockport.
1889	Knowles, John, Brynn Mount, Westwood, Lower Ince, near Wigan.
1904	Landless, J. E., Habergham Colliery, Burnley.
1890	Law, J. Illingworth, Waterfoot, Manchester.
1897	Lees, Frederick, J.P., The Rookery, Ashford, Bakewell.
1899	Leigh, Oswald B., North Lincoln House, Frodingham, Lincolnshire.

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Year of Election.	Names and Addresses.
1898	Livesey, John, Rose Hill Colliery, Bolton.
1905	Lord, Chadwick, Jubilee Colliery, Crompton, Oldham.
1898	Lowe, Henry, Chisnall Hall Colliery, Coppull, near Wigan.
1902	Machin, Thomas H., Hyde Lane Colliery, Hyde, Cheshire.
1903	Marshall, Eustace, The Larches, Wigan.
1892	Mathews, D. H. F., H.M. Inspector of Mines, Hoole, Chester. *Vice-President.*
1893	Matthews, E. L., Imperial Iron Works, Pendleton, Manchester.
1896	Matthews, Thomas, Imperial Iron Works, Pendleton, Manchester.
1901	McKay, William, Grenville Terrace, Dukinfield, Cheshire.
1892	Miller, Arthur, Bredbury Colliery, near Stockport.
1892	(*d*) Mills, David, Bradford Street, Farnworth.
1895	Mitton, A. Dury, Assoc.M.Inst.C.E., 128, Abbey Foregate, Shrewsbury. *Member of Council.*
1901	Morrison, Daniel, 41, John Dalton Street, Manchester.
1904	Mountain, M. B., Elton Grange, Bury.
1904	Nicholson, J., Jun., Prudential Buildings, Nelson Square, Bolton.
1900	Ollerenshaw, W., Manager, Denton Colliery, Denton, Manchester. *Member of Council.*
1903	Orrell, G. Harold, Albany Chambers, Bolton.
1883	Peace, George Henry, M.Inst.C.E., Monton Grange, Eccles. *Member of Council.*
1905	Percy, Frank, 3, Springfield Street, Wigan.
1900	Pickstone, William, 5, Moor Lane, Kersal, Manchester. *Member of Council.*
1906	Pickup, W. Elmwood, Rishton, near Blackburn.

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Year of Election.	Names and Addresses.
1879	Pilkington, Charles, J.P., The Headlands, Prestwich, Manchester. *Vice-President.*
1873	Pilkington, Edward, J.P., Clifton, Manchester. *Past-President.*
1899	Pilkington, Lawrence, South Garth, Eccles Old Road, Pendleton, near Manchester.
1903	Pilkington, Lionel E., Haydock, St. Helens.
1877	Place, W. H., Hoddleston Collieries, Darwen.
1887	Platt, Samuel Sydney, M.Inst.C.E., F.G.S., Morredge Sudden, Rochdale.
1904	Pope, P. C., 196, Deansgate, Manchester. *Member of Council.*
1904	Power, Thomas, The Commons, Thurles, Ireland.
1904	Preece, G. G. L., 30, Great Western Street, Moss Side, Manchester.
1891	Prestwich, Joseph, 72, Eccles Old Road, Pendleton, Manchester.
1904	Ramsden, Cecil Sydney, 42, Deansgate, Manchester.
1897	Richardson, Isaiah, Blainscough Collieries, Coppull, near Chorley.
1900	Ridyard, G. J., Shakerley Collieries, Tyldesley.
1860	Ridyard, John, F.G.S., Hilton Bank, Little Hulton, Bolton. *Past-President.*
1904	Rigby Harold, Greville Lodge, Winsford, Cheshire.
1893	Rigby, John, Greville Lodge, Winsford, Cheshire.
1903	Ritson, Thomas F., Bamfurlong Collieries, near Wigan.
1897	Ritson, W. A., 4, Booth Avenue, Withington, Manchester.
1889	Robinson, John, Haydock Collieries, St. Helens.
1903	Rogers, W., Lever Edge Lane, Bolton.
1892	Roscoe, George, Peel Hall Collieries, Little Hulton, Bolton.
1898	Roscoe, Thomas, The Old Hall, Mottram, Manchester.
1905	Ross, A., Moston Colliery, near Manchester.
1895	Rothwell, Samuel, 21, Chorley New Road, Bolton.
1903	Rushton, A., Maypole Colliery, Abram, near Wigan.
1895	Ryans, Joseph, Arigna Mines, Carrick-on-Shannon.

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Year of Election.	Names and Addresses.
1905	Saike, Yoshima, Jagawa Colliery, Buzen, Japan.
1887	Saint, William, H.M. Inspector of Mines, Kersal Bank, Higher Broughton, Manchester. *Past-President.*
1888	Scarborough, George Edward, Newton and Meadows Collieries, Wigan.
1905	Scholes, T., Oswaldtwistle Collieries, near Accrington.
1889	Scott, William B., Eversley Cottage, Middleton, near Manchester.
1891	Scowcroft, Thomas, J.P., Redthorpe, Bromley Cross, near Bolton.
1904	Settle, William, Prestwich, Manchester.
1899	Shaw, Alfred, Bersham Colliery, Wrexham.
1905	Smith, John, Bower Colliery, Hollinwood, Oldham.
1888	Smith, Sydney A., Assoc.M.Inst.C.E., 1, Princess Street, Albert Square, Manchester. *Hon. Secretary.*
1903	Spackman, Charles, Rosehaugh, Clitheroe.
1905	Speakman, F., Church Street, Leigh, Lancashire.
1886	Speakman, Harry, Bedford Collieries, Leigh, Lancashire.
1904	Spencer, R. S., New Moss Colliery, Audenshaw, near Manchester.
1905	Stewart, J. E., c/o Pekin Syndicate, Ltd., Tientsin, North China
1882	Stopford, T. R., Woodley, Radcliffe, near Manchester.
1903	Sutcliffe, W. H., F.G.S., Shore Cottage, Littleborough. Rochdale.
1905	Takagi, Kiichiro, The Mitsui Mining Co., Tagawa, Buzen, Japan.
1899	Tansley, A. E., Springfield House, Coppull, Chorley.
1901	Taylor, J. T., 51, Park Road, Darwen.
1905	Thompson, Fred J., Osborne Bank Esplanade, Fleetwood.
1892	Thompson, James, Westhoughton Road, Westhoughton, Bolton.
1891	Tonge, Alfred J., Hulton Collieries, near Bolton. *Member of Council.*
1898	Tonge, James, F.G.S., Westhoughton, near Bolton.
1895	Travers, T. W., Spring Bank, Broad Oak Park, Worsley, near Manchester.

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Year of Election.	Names and Addresses.
1876	Unsworth, John, J.P., Scot Lane Collieries, Blackrod, near Chorley.
1904	Walker, Howard J., Bank Chambers, Wigan.
1882	Wall, Henry, Rowbottom Square, Wallgate, Wigan.
1893	Wallwork, Jesse, Bridgewater Collieries, Walkden, near Manchester. *Member of Council.*
1905	Walshaw, J., Astley and Tyldesley Collieries, Tyldesley, near Manchester.
1897	Walton, Thomas, Colliery Offices, Bank Parade, Burnley.
1905	Waterworth, Joseph, Westleigh Collieries, Leigh.
1880	Watts, William, Assoc.M.Inst.C.E., F.G.S., Underbank Hall, Deepcar, near Sheffield. *Past-President.*
1891	Whitehead, J. J., P.O. Box 6,407, Johannesburg.
1905	Whitworth, C. S., 24, Montgomery Street, Hollinwood, Oldham.
1905	Wilkinson, H. Tatlock, 196, Deansgate, Manchester.
1897	Winstanley, George H., F.G.S., 42, Deansgate, Manchester. *Member of Council. Hon. Auditor.*
1876	Winstanley, Robert, C.E., 42, Deansgate, Manchester. *Past-President.*
1897	Wood, John, Barley Brook Foundry, Wigan.
1897	Wood, Percy Lee, Clifton and Kersley Coal Co., Ltd., Clifton, Manchester.
1904	Wood, Thomas, Barley Brook Foundry, Wigan.
1895	Wordsworth, T. H., New Moss Colliery, Audenshaw, near Manchester.
1904	Young, W., Slievardagh Collieries, Ballynonty, Thurles, Ireland.
1906	Young, William, 533, Bickershaw Lane, Bickershaw, Wigan.

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Year of Election.	Names and Addresses.
	ASSOCIATE MEMBERS.—(FEDERATED.)
	Assoc.M.Inst.M.E.
1904	Blackwell, G. G., The Albany, Old Hall Street, Liverpool.
1905	Mellor, Edward Thomas, F.G.S., The Geological Survey Office, Box 435, Pretoria, Transvaal.
1905	Preston, S. C., Close House, St. Helens.
1906	Rogers, James Taylor, Calder Cottage, Littleboro.
1905	Ross, Arthur, 1, Glengall Road, Old Kent Road, London, S.E.
	ASSOCIATES.—(FEDERATED.)
	Assoc.Inst.M.E.
1898	Dickinson, Archibald, 283, Colne Road, Burnley.
1902	Jobes, R. A., 98, Carley Road, Sunderland.
1905	Woodward, W., 196, Deansgate, Manchester.
	STUDENTS.—(FEDERATED.)
	Stud.Inst.M.E.
1904	Crankshaw, H. M., Montcliffe, Horwich, near Bolton.
1905	Cross, Charles Oliver, 2, Percy Road, Wrexham.
1905	Entwisle, George, The University, Birmingham.
1904	Hark, J. R., 92, Market Street, Hindley, Wigan.
1904	Macalpine, G. L., M.Sc., Altham and Great Harwood Collieries, Accrington.
1904	Munroe, Martin, The Bengal Coal Co., Ltd., Raghara, India.
1904	Ormond, Percy, Torisholme, Earlestown, Lancashire.
1904	Robinson, Fred J., The Grange, Haydock, Lancashire.
1906	Spencer, John, 3, Major Street, Crawshawbooth, near Manchester.
1904	Tong, F. N., Spring Bank, Astley Bridge, near Bolton.
1904	Turner, Charles, Irlam, near Manchester.

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Year of Election.	Names and Addresses.
	MEMBERS—(NON-FEDERATED).
1897	Allen, Edward, Willow Bank, Hale, Bowdon, Cheshire.
1903	Aroksamy, M. R., 175, Oxford Street, Secundarabad (Deccan), India.
1895	Barnes, J., F.G.S., 301, Great Clowes Street, Higher Broughton. *Past-President. Hon. Auditor.*
1881	Black, W. G., F.R.C.S.Ed., F.G.S., 2, George's Square, Edinburgh.
1900	Brancker, Richard, 11, Old Hall Street, Liverpool.
1900	Burke, Harry.
1903	Bury, A., 280, Higher King Street, Hurst, Ashton-under-Lyne.
1903	Campbell, H. H., 444, Produce Exchange Buildings, Manchester.
1894	Cole, Robert H., Endon, Stoke-on-Trent.
1904	Collier, Rev. E. C., M.A., St. Peter's Vicarage, Birkdale, Southport.
1879	Crawford and Balcarres, the Right Hon. the Earl of, Haigh Hall, Wigan. *Past-President.*
1900	Davidson, Robert.
1856	Dickinson, Joseph, F.G.S., Hon.M.I.M.E., South Bank, Sandy Lane, Pendleton. *Past-President. Trustee.*
1903	Edmondson, J. H., Garswood Hall Collieries, Wigan.
1900	Elce, A., 272, Crow Lane West, Newton-le-Willows, Lancashire.
1903	Gillott, J. W., Lancaster Works, Barnsley.
1892	Gregson, G. Ernest, 11, Chapel Street, Preston.
1881	Hall, Henry, I.S.O., H.M. Inspector of Mines, Rainhill, Prescot, R.S.O., Lancashire. *Past-President.*
1898	*Hall, Levi J., Morland House, Birch Vale, near Stockport.
1897	Heather, Frank, 47, Mosley Street, Manchester.
1900	Henshaw, A. M., Talk-o'th'-Hill Collieries, Staffordshire.

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Year of Election.	Names and Addresses.
1902	Hewitt, J., 114, Bell Green Lane, Ince, Wigan.
1876	Higson, John, M.Inst.C.E., F.G.S., 18, Booth Street, Manchester.
1900	Hinnell, H. Leonard, M.Inst.C.E., 41, Corporation Street, Manchester.
1897	Hobson, Bernard, M.Sc., F.G.S., Victoria University, Manchester.
1897	Howsin, Evelin G., Simonstown, Burnley, Lancashire.
1895	Hutchinson, John William, The Lewis Merthyr Consolidated Collieries, Ltd., Hafod, near Pontypridd.
1883	Jobling, Albert, 91, Rectory Road, Burnley.
1883	Jobling, Henry, 91, Rectory Road, Burnley.
1893	Kenrick, John P., 8, St. James's Square, Manchester.
1901	Knight, Henry, Manager, Rose Bridge and Ince Hall Collieries, Wigan.
1898	Krauss, John Samuel, B.A., Stonycroft, Knutsford Road, Wilmslow, Cheshire.
1898	Landless, Richard, Bank Hall Colliery, Burnley.
1902	Latham, Daniel, Rose Bridge and Ince Hall Collieries, Wigan.
1884	Leech, A. H., Brinsop Hall Colliery, Wigan.
1887	Lord, James, Hill House, Rochdale.
1881	Macalpine, G. W., Broad Oak, Accrington.
1898	Naylor, Alfred, Ibstock Collieries, near Leicester.
1897	Noar, T. Lamb, 52, Cannon Street, Manchester.
1903	Owen, Richard, Messrs. Pearson & Knowles' Collieries, Wigan.
1897	*Pickup, P. W. D., Rishton Collieries, Rishton, near Blackburn.
1903	Ramsbottom, James, Church Road, New Mills, Stockport.
1897	Reid, Alexander, Pekin Syndicate Limited, Shanghai, China.

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Year of Election.	Names and Addresses.
1902	Salisbury, S., 62, Ayres Road, Brooks' Bar, Manchester.
1899	Selby, John B., Atherton Hall, Leigh, Lancashire.
1882	Settle, Joel, The Hill, Alsagar, Stoke-on-Trent.
1887	Shuttleworth, The Right Hon. Lord, of Gawthorpe, Burnley. *Past-President.*
1884	*Simpson, W. W., Winkley, near Whalley, Blackburn.
1864	*Smethurst, William, F.G.S.
1881	Smith, John, Bickershaw Collieries, Westleigh, near Manchester.
1873	*Smith, R. Clifford, F.G.S., Ashford Hall, Bakewell. *Past-President.*
1881	Squire, J. B., Assoc.Inst.C.E., F.G.S., 101, Clifton Hill, St. John's Wood, London, N.W.
1891	Sutcliffe, Richard, Horbury, near Wakefield.
1889	Taylor, William, 51, Park Road, Darwen.
1897	Tickle, James, Bamfurlong Collieries, Bamfurlong, Wigan.
1893	Timmins, Arthur, Assoc.M.Inst.C.E., F.G.S., Argyll Lodge, Higher Runcorn.
1886	*Trafford, Sir Humphrey Francis de, Bart., F.G.S., 13, Charles Street, Berkeley Square, London, W.
1887	Walkden, Richard, Colliery Manager, 26, Watery Lane Terrace, Springvale, Darwen.
1882	Walker, T. A., Pagefield Iron Works, Wigan.
1888	*Walmesley, Oswald, 2, Stone Buildings, Lincoln's Inn, London, W.C.
1892	Ward, Alexander Haustonne, Raneegunge, Bengal, India.
1903	Wasley, J. C., 184, Saltwell Road, Gateshead.
1897	Wells, Lionel B., M.Inst.C.E., 75, Haworth's Buildings, 5, Cross Street, Manchester. *Member of the Council.*
1880	Williams, Sir Edward Leader, M.Inst.C.E., Ship Canal Company, Spring Gardens, Manchester.
1886	*Wood, Guy.

Members are requested to communicate to the Hon. Secretary all changes of address, also any omissions, or corrections required in the list.

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MANCHESTER GEOLOGICAL & MINING SOCIETY.

(Federated with the Institution of Mining Engineers.)

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TRANSACTIONS, PROCEEDINGS, &c.

Belfast.—Natural History and Philosophical Society. Report and Proceedings for Session 1902-03, 1903-04. *From the Society.*

Birmingham.—South Staffordshire and East Worcestershire Institute of Mining Engineers. Proceedings. Included in the Transactions of the Institution of Mining Engineers. List of Members, 1904-5. *From the Institute.*

Bradford.—33rd, 34th, 35th, and 36th Annual Reports of Libraries and Art Museum Committee. *From the Committee.*

Bristol.—Museum and Reference Library. Reports for 1903, 1904, 1905. *From the Committee.*

Cambridge.—Museum. 37th, 38th, 39th, 40th Annual Reports, Museums and Lecture Rooms' Syndicate, 1903, 1904, 1905, 1906. *From the Woodwardian Museum.*

Cambridge.—Philosophical Society. Proceedings. Vol. XII., Part 6. *From the Society.*

Cardiff.—Naturalists' Society. Report and Transactions for 1902-03, 1903-04. Vols. XXXVI., XXXVII. *From the Society.*

Cardiff.—South Wales Institute of Engineers. Proceedings. Nos. 1, 2, 3, 4, 5, Vol. IX. No. 5, Vol. XIV. Nos. 6, 7, 8, Vol. XXIII. Nos. 1, 2, 3, 4, 5, 6, 7, Vol. XXIV. *From the Institute.*

Chester.—Annual Reports of Chester Society of Natural Science and Literature for 1903, 1904, 1905. *From the Society.*

Derby.—Midland Counties Institution of Engineers.—Proceedings. Included in the Transactions of the Institution of Mining Engineers. *From the Institution.*

Dublin.—Royal Dublin Society. Parts 1, 2, 3, Vol. X. Parts 1, 2, 3, 4, 5, 6, 7, 8, 9, Vol. XI. Scientific Transactions. Parts 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, Vol. VIII. Parts 1, 2, Vol. IX. Economic Proceedings, Vol. I., Part 4, 8. *From the Royal Irish Academy.*

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Edinburgh.—Royal Physical Society. Procedings. 1901-02, 1902-03, 1903-04. *From the Society.*

Glasgow.—Natural History Society. Transactions. Part 3, Vol. VI. Parts 1, 2, 3, Vol. VII. *From the Society.*

Hamilton.—Mining Institute of Scotland. Transactions. Included in the Transactions of the Institution of Mining Engineers. Separate, Vol. XXVIII., Parts 4 and 5; Supplemental Part, 1905. *From the Institute.*

Hertford.—Hertford Natural History Society and Field Club. Transactions. Parts 7, 8, 9, Vol. XI. Parts 1, 2, 3, 4, 5, 6, Vol. XII. *From the Society.*

Leeds.—Literary and Philosophical Society. 83rd Annual Report, 1902-03, 1903-04. *From the Society.*

Leeds.—Yorkshire Geological and Polytechnic Society. (Now Yorkshire Geological Society.) Proceedings. Nos. 1, 2, 3, Vol. XV. *From the Society.*

Leicester.—Literary and Philosophical Society. Transactions. Vols. VII., VIII., IX., X. *From the Society.*

Liverpool.—Science Students' Association. Annual Report, 1903-4. *From the Association.*

Liverpool.—Geological Society. Proceedings. Parts 3, 4, Vol. IX. Part 1, Vol. X. *From the Society.*

Liverpool.—Public Libraries and Art Galleries. Annual Reports, 1903, 1904, 1905. *From the Committee.*

London.—British Association for the Advancement of Science. The President's Address and the Sectional Addresses. Reports for 1903, 1904, 1905. *From the Association.*

London.—British Museum Catalogues. Tertiary Vertebrata. Catalogue of Fossil Plants in the Department of Geology. *From the Museum.*

London.—Geological Magazine. (New Series.) Decade IV. Nos. 10, 11, 12, Vol. X. Decade V. Nos. 1-12, Vol. II. Nos. 1-12, Vol. III. *Purchased.*

London.—Geological Society. Quarterly Journal. Nos. 236-247. Geological Literature added to the Geological Society's Library, 1903, 1904, 1905, and Lists of the Geological Society. *From the Society.*

London.—Geologists' Association. Proceedings. Vols. XVIII., XIX. List of Members of the Geologists' Association for 1904, 1905. *From the Association.*

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London.—Institution of Mechanical Engineers. Proceedings. Nos. 2, 3, 4, 1903, and List of Members, 1902. Nos. 1-4, 1904, Nos. 1-4, 1905. *From the Institution.*

London.—Iron and Coal Trades' Review. Nos. 1857 to 2013. *From the Publishers.*

London.—Iron and Steel Institute. Journal. No. 2, 1903. Nos. 1, 2, 1904. Nos. 1, 2, 1905. No. 1, 1906. Supplement Vol. LXV. Rules and List of Members. *From the Institute.*

London.—Marine Biological Association. Journal. No. 3, Vol. VII. *From the Association.*

London.—Palæontographical Society. Vol. LVII., LVIII., LIX., for 1903, 1904, 1905. *Purchased.*

London.—Royal Society. Proceedings. Nos. 482 to 524. Reports to the Evolution Committee, II., III. Reports of the Sleeping Sickness Commission. Obituary Notices, Parts 1-4. *From the Society.*

London.—The Colliery Guardian. Nos. 2131 to 2387. *From the Publishers.*

London.—The Mining Journal. Nos. 3554 to 3709. *From the Publishers.*

Manchester.—Association of Engineers. Transactions. 1903, 1904, 1905. *From the Association.*

Manchester.—Literary and Philosophical Society. Memoirs and Proceedings. Part 6, Vol. XLVII.; Parts 2-3, Vol. XLVIII.; Parts 1, 2, 3, Vol. XLIX.; Parts 1, 2, 3, Vol. L. *From the Society.*

Manchester Geographical Society. Journal. Vols. XIX., XX., XXI. *From the Society.*

Manchester.—Field Naturalists' Society. Report and Proceedings for the years 1903, 1904, 1905. *From the Society.*

Manchester.—The Owens College Museum. Reports for the years 1900-1906. Publication, Nos. 50, 54, 56. Notes of the Museum, Nos. 17-21. *From the College.*

Newcastle-upon-Tyne.—Institution of Mining Engineers. Transactions. Vols. I.-V., XVI., XIX.; Part 4, Vol. X.; Part 4, Vol. XXII.; Parts 3, 7, Vol. XXIII. Vols. XXIV., XXV., XXVI., XXVII.; Parts 1, 2, 3, 4, Vol. XXVIII.; Parts 1, 2, 3, 4, 5, Vol. XXIX.; Parts 1, 2, 3, 4, 5, Vol. XXX. Parts 1, 2, 3, 4, Vol. XXXI. *From the Institution.*

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Newcastle-upon-Tyne.—North of England Institute of Mining and Mechanical Engineers. Transactions. Included in the Transactions of the Institution of Mining Engineers; Annual Reports, 1901-1906; Subject Matter Index of Mining, Mechanical and Metallurgical Literature for 1901, 1902; Report of the Committee upon Mechanical Coal Cutters, Part II. *From the Institute.*

Norwich.—Norfolk and Harwich Naturalists' Society. Transactions. Part 5, Vol. VII.

Rugby.—Rugby Engineering Society. Transactions. Vol. I., Session 1903-04.

Salford.—The Annual Report of Libraries, Museum, and Parks Committee for the Borough of Salford, 1902-3, 1903-4, 1904-5.

Sheffield.—Midland Institute of Mining, Civil, and Mechanical Engineers. Proceedings. Included in the Transactions of the Institution of Mining Engineers. *From the Institution.*

Stafford.—North Staffordshire Field Club. Annual Report and Transactions, 1903-4, 1904-5, 1905-6. *From the Club.*

Stoke-upon-Trent.—North Staffordshire Institute of Mining and Mechanical Engineers. Transactions. Included in the Transactions of the Institution of Mining Engineers. List of Members, 1904, 1905. *From the Institute.*

Wigan.—Science and Art of Mining. Vols. XIV., XV., XVI., XVII.

BOOKS, &c., PURCHASED.

"The Law of Mines, Quarries, and Minerals," by Robert Forster MacSwinney, M.A. 2nd edition. (1897.)

"The Law of Mines and Minerals," by William Bainbridge, F.G.S. 5th edition. (1900.)

"Petrology for Students," by A. Harker, M.A. (1902.)

"Scenery of Scotland," by A. Geikie, D.Sc. (1901.)

"Field Geology," by W. H. Penning, (1894.)

"Iron Ores of Great Britain," by J. D. Kendall. (1893.)

"The Steam Turbine," by R. M. Neilson. (1903.)

"Potts' Mining Register." (1903.)

"Scenery and Geology of the Peak of Derbyshire," by E. Dale. (1900.)

"Text-Book of Coal Mining," by W. H. Hughes. (1904.)

"Bacon's County Atlas."

"Times Atlas."

"Geological Photographs." Part 3.

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BOOKS, PAMPHLETS, &c., PRESENTED.

"De Vi Physica," by Francis G. Bain, M.A. *Presented by Messrs. Parker & Co., Publishers, London.*

"Man's Responsibility," by T. G. Carson. *Presented by the Author.*

"Observations of Rain and Dust and Evaporation in Edinburgh in 1903." *Presented by Dr. W. G. Black, F.R.C.S.*

"Economic Minerals of Nova Scotia; Catalogue and Description Halifax, N.S." *Presented by Edwin Gilpin, Esq., H.M.I.M.*

"First Report of the Royal Commission on Coal Supplies." Vols. I., II., III. *Presented by Prof. H. Bailey Dixon, M.A.*

Papers presented by W. Whitaker, Esq., B.A., F.R.S., &c.: "The Present Shortage of Water Available for Supply." (Disc.) "Geology of Cornwallis or McNab's Island, Halifax Harbour, Canada," by Rev. W. H. Man, D.C.L.

Roy. Soc. Philos. Transactions, Vol. CLXXIX. (1888). "Skull, Brain and Auditory Organ of a New Species of Pterosaurain (Scaphognathus Purdoni), from Upper Lias, near Whitby, Yorkshire." Vol. CLXXXIV. (1892). "Some New Reptiles from the Elgin Sandstone." Vol. CLXXXV. (1894). "Reptiles from Elgin Sandstone—Discovery of two New Genera," (all) by E. T. Newton, F.L.S.

"Reports of the Director General of the Geol. Survey of the United Kingdom, 1855 to 1889."

Reports of Government Geologist of South Australia, 1882-3. "Geological Character of the Country passed over from Port Augusta to Eucla." "Echunga Goldfield." "Geology of Country East of Farnia." "Geological Character of Barossa, and Parr Wirra." "Ulooloo Goldfield." "Journey from Adelaide to Hale River." "Geological Map of the Tertiary Deposits of the Hundred of Barossa." "Journey from Warrina to Musgrave Ranges." "Geological Examination of the Country in neighbourhood of Alice Springs." "Coal Bearing Area in neighbourhood of Lugh's Creek."

Institution of Civil Engineers. Minutes of Proceedings. Vols. XLI. to CXIV. *Presented by Lt.-Col. Sir Lees Knowles, Bart., M.A., LL.M., D.L.*

Papers.—"Le Couffre et la Riviére Souteraine de Padirac (Lot)." "Les Expériences a la Flouresceine et la Circulation des Eaux sous les Glaciers." "Inaptitude des Stalagmites." "Circulation des Eaux Souterraines." "Bulletin des servises

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de la carte Geologeque de la France." "La necessité et les Moyens de protíger les Grandes Sources des Terrains Calcaires de France." "Les Chouruns du Dévoluy." "Les Récentes Explorations Souterraines (1884-1900)." "Ouziense Campagne Souterraine (1898)." "Eu Auvergue sur la Route des Causses." "L'emploi de la Flourescéine en Hydrologie." "Report on Hygiéne." "Unversalité et Aucunneté des Phénoménes Carerueux du Calcairi." *Presented by the Author (Mons. E. A. Martel).*

"Pleistocene Clays and Sands on the Isle of Man," by T. Mellor Reade and Joseph Wright. *Presented by the Authors.*

"Sands and Sediments," by T. Mellor Reade and Philip Holland. *Presented by the Authors.*

"Shaft Guides and Safety Catches." *Presented by the "Colliery Guardian."*

"Sundry Geological Problems." *Presented by the Author (G. Henriksen).*

Brief Outline of the Mining Department of the Hokkaido Colliery and Railway Co. (1903.) *Presented by Kiyotsugu Yorieksa.*

"Redevelopement of the State Trade in Ireland," by G. H. Kinahan, M.R.I.A. *Presented by the Author.*

Reminiscences: Army Medical Service, by Surgeon-Major W. T. Black. *Presented by Surgeon-Major W. G. Black, F.R.C.S. (Edin.).*

The Position of the Transvaal Coal Measures in the Karroo Sequence. *Presented by E. T. Mellor, Esq.*

The South Rand Goldfield, Transvaal. The Transvaal Kromdraai Conglomerates. Anniversary Address to the Geologieal Society of South Africa (1905). *Presented by A. R. Sawyer, Esq.*

Reports.

Mines and Quarries. 1902, 1903, 1904, 1905; also H.M. Inspector's Report of Mines and Quarries for the S. W. District for 1903, 1904, 1905. Ankylostomiasis. Report on the Outbreak in the Westphalian Colliery District. *Presented by J. S. Martin, Esq., I.S.O., H.M. Inspector of Mines.*

Mines and Quarries. District Report (No. 7) for the Year 1903. *Presented by Henry Hall, Esq., I.S.O., H.M. Inspector of Mines.*

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SOUTH AFRICA.

Pretoria.—Geological Survey of the Transvaal. Report for 1904. *Presented by the Commissioner of Mines.*

INDIA.

Calcutta.—Memoirs of the Geological Survey of India. No. 3, Vol. XXXII.; No. 3, Vol. XXXIII.; No. 3, Vol. XXXIV.; No. 2, Vol. XXXV.; No. 1, Vol. XXXVI.; and General Report of Geological Survey, April 1st, 1902, to March 31st, 1903. Contents and Index, Vols. XXI.-XXX. of the Records (1887-1897). Records, Vol. XXXI., Parts 1-2. *From the Director of the Survey.*

Report of the Inspector of Mines in India, 1894-8. Reports on Inspection of Collieries. "Smjareni Colliery, Yellandu, Hyderabad (Deccan.), 1895." "Gold Mines in the Mysori State, South India, 1894." "Daudat and Pidh Mines, Salt Range, near Rhewrah, Jhelum District, Punjab." "Mayo Salt Mine, Salt Range." "Assam Ry. and Trading Co., Ltd., Assam." "Khost and Shahrig Coal Mines, Baluchistan." "Khost Coal Mines, Baluchistan (1896)." *Presented by James Grundy, Esq., H.M. Inspector of Mines in India.*

AUSTRALIA.

Adelaide.—Geological Survey. "Northern Territory of South Australia. Report on the Gold Discoveries near Wenneki." "Depôt and Mines on the Arltunga Goldfields, MacDonnell Ranges." Short Review of Mining Operations in the State of South Australia, 1903. *Presented by the Government Geologist.*

Adelaide.—Royal Society of South Australia. Transactions. Vols. XXVII., XXVIII., XXIX. *From the Society.*

Brisbane.—Queensland Government Mining Journal. Nos. 38 to 43, Vol. IV.; Nos. 44-49, Vol. V. Annual Report for 1903. Report on the North West Coast Mineral Deposits. *Presented by the Agent-General for Queensland.*

Melbourne.—The Australian Mining Standard. Nos. 772 to 790, Vol. XXX.; Nos. 791 to 816, Vol. XXXI.; Nos. 817 to 823, Vol. XXXII. *From the Editor.*

Sydney.—Mineral Resources of New South Wales, and Annual Report of the Department of Mines and Agriculture for the year 1903. Memoirs. No. 3. Records (Geological Survey). Vols. VII., VIII. *From the Hon. the Minister of Mines.*

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Canada.

Halifax.—Mining Society of Nova Scotia. Journal. Vol. VII.

Ottawa.—Geological Survey of Canada. Report on the Altitudes in the Dominion of Canada, by J. White, F.R.S.S. Profiles accompanying above Report (with a Relief Map of North America). Sheets 1, 2, 3, 4. Canadian Pacific Railway. Dictionary of Altitudes. Map showing Mounted Police Stations in North West Canada, 1904. Catalogue of Canadian Birds. Part 2. Geological Sheets Nos. 42 to 48, 56, 57, 58. Publications, Nos. 398, 685, 694, 423, 424, 425, 426, 429, 615, 436, 447, 449, 450, 451, 452, 453. Check List of Canadian Plants. Descriptive Notes on Certain Implements, &c. A History of New Brunswick Geology. On the Nepholine Rocks of the Ice River.

St. John, New Brunswick.—Natural History of New Brunswick. Bulletin No. XXII. *From the Society.*

Ottawa.—Canadian Mining Institute Journal, 1903. Indices to Transaction, 1891-1903. Report of Council, 1903.

U. S. America.

Boston.—Technological Quarterly, No. 2.

Cambridge.—Harvard College. Bulletin of the Museum of Comparative Zoology. No. 9, Vol. XXXIX.; No. 7, Vol. XL.; Vol. XLI., No. 2; Vol. XLIII., Nos. 1, 2, 3, 4; Vol. XLIV.; Vol. XLV., Nos. 1, 2, 3, 4; Vol. XLVI., No. 1. Annual Reports of the Museum of Comparative Zoology for 1902-3, 1903-4, 1904-5. Geological Series. Nos. 4, 5, Vol. VI. *From Alex. Agassiz, Esq.*

Carolina, N.—Elisha Mitchell Scientific Society Journal. Parts 1, 2, 3, Vol. XX.; Parts 1, 2, 3, Vol. XXI.; Parts 1, 2, Vol. XXII.

Chicago.—Field Columbian Museum. Report Series, Nos. 3, 4, 5, Vol. II. Zoological Series, Nos. 10 to 16, Vol. III.; Nos. 1, 2, Vol. IV.; Nos. 1, 2, 3, Vol. VII. Geological Series, Vol. II., Nos. 2, 3, 4; Vol. III., Nos. 1-4; Vol. VI. Nos. 1, 10, 14. *From the Museum.*

Colorado Springs.—Colorado College Scientific Society. College Studies. Vol. X., XI., XII.

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Denver.—Colorado Scientific Society. Proceedings, 1897-1900. Vol. VII., pp. 109-138, 267-312.

Des Moines.—Geological Survey of Iowa. Vols. XIII., XIV., XV. *From the Director of the Survey.*

Houghton, Michigan.—Michigan College of Mines. Year-Book, 1903-1904, and List of Graduates.

Madison.—Wisconsin Geological and Natural History Survey. Bulletin. Nos. 9, 10, 11, 12. Transactions. Vols. XIII., XIV.

Minneapolis.—The American Geologist. Vols. XXXII., XXXIII., XXXIV., XXXV., XXXVI. *Purchased.*

New York.—The American Museum of Natural History. Bulletin No. 2, Vol. XVIII.; Vols. XIX., XX., XXI. Memoirs. Vol. I., No. 8. Annual Report for 1903. *From the Museum.*

New York.—Compressed Air. Vol. X., Nos. 11, 12; Vol. XI., No. 1. *From the Publishers.*

New York.—American Institute of Mining Engineers. Transactions. Vols. XXXII., XXXIII., XXXIV., XXXV., XXXVI. Pamphlets. List of Members, Officers, Rules, &c., 1903. Bulletin, 1905, 1906.

Philadelphia.—Franklin Institute. Journal. Vols. CLVI., CLVII., CLVIII., CLIX., CLX., CLXI. *From the Institute.*

Philadelphia.—Academy of Natural Sciences. Proceedings. Vols. LV., LVI., LVII. *From the Academy.*

Philadelphia.—American Philosophical Society. Proceedings. Nos. 173, 174, 175, 176, 177, 178, 179, 180, 181.

Scranton, Pa.—Mines and Minerals. Vols. XXIV., XXV., XXVI. *From the Editor.*

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Toronto .....Canadian Institute, 58, Richmond Street, East.

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*Mining and Geological Institute of India.

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Liege.....*Revue Universelle des Mines de la Métallurgie, 18, Ruebonne-Femme, 18.

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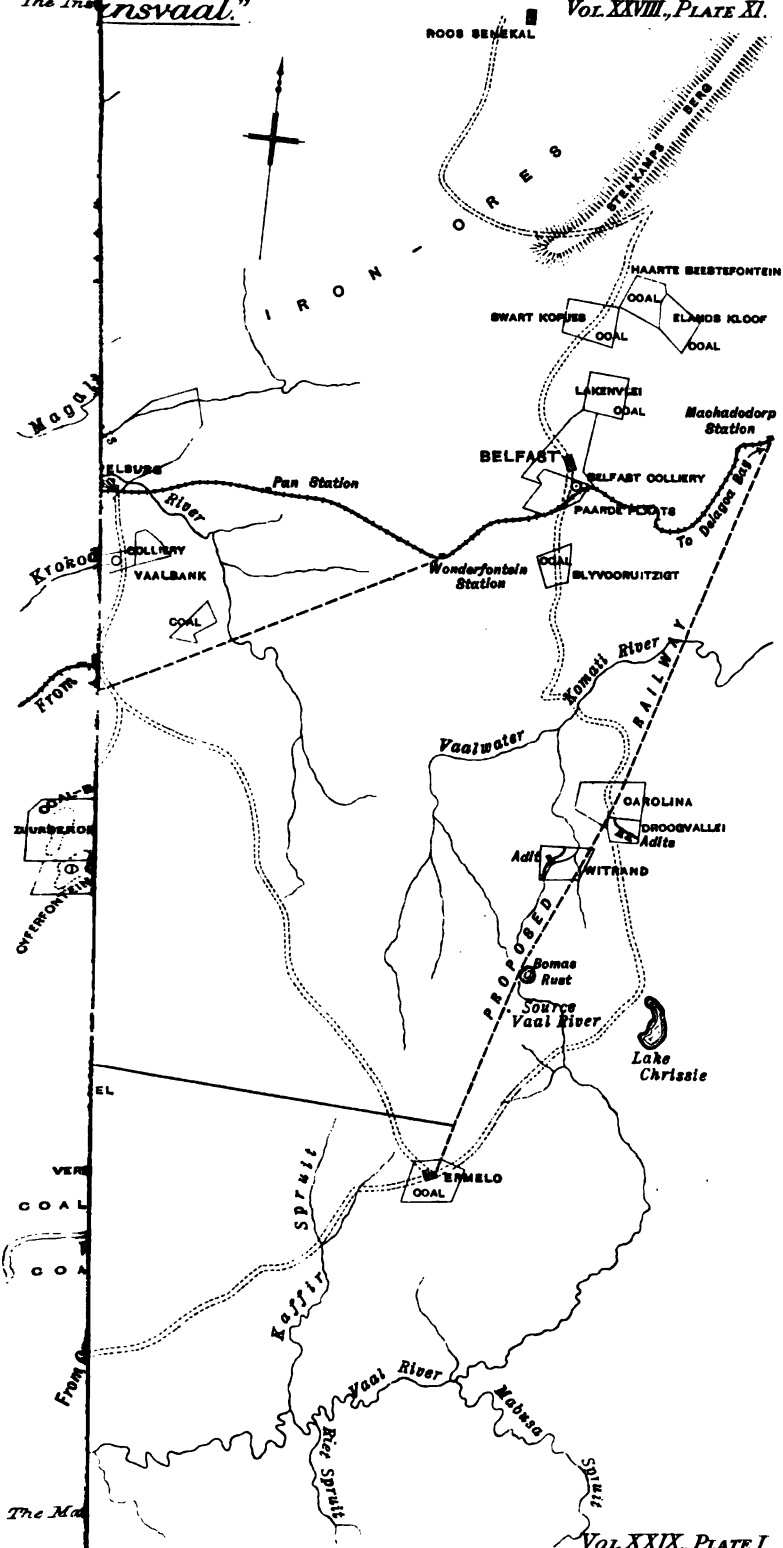

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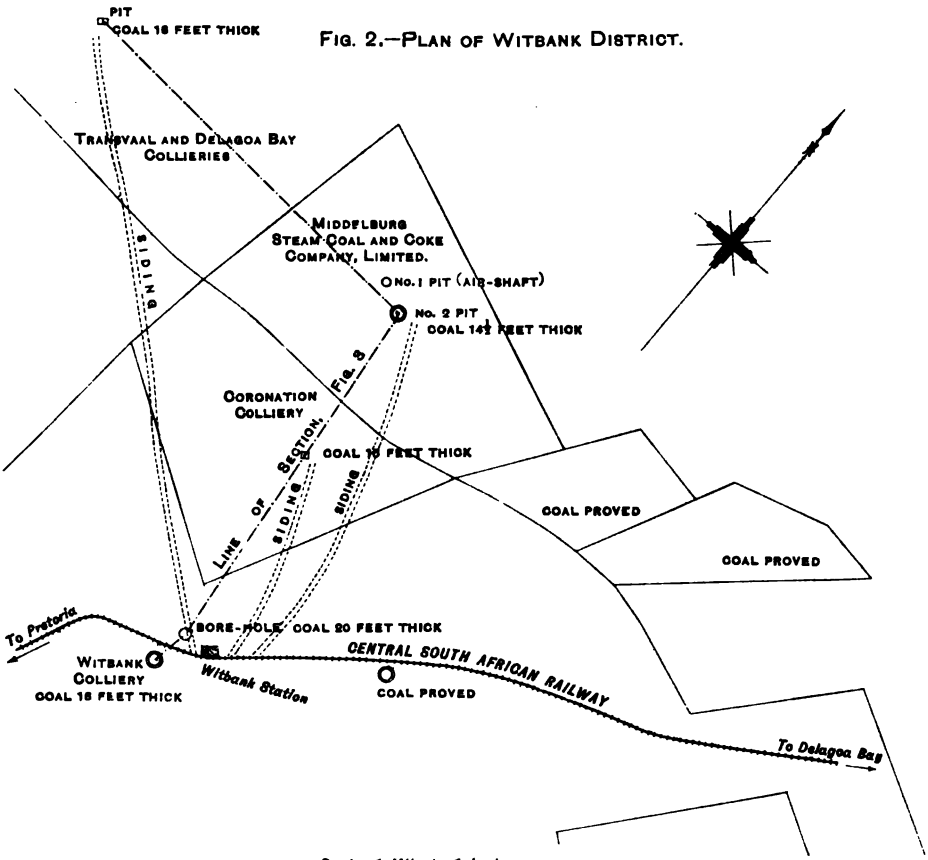
Transactions.1904-1905

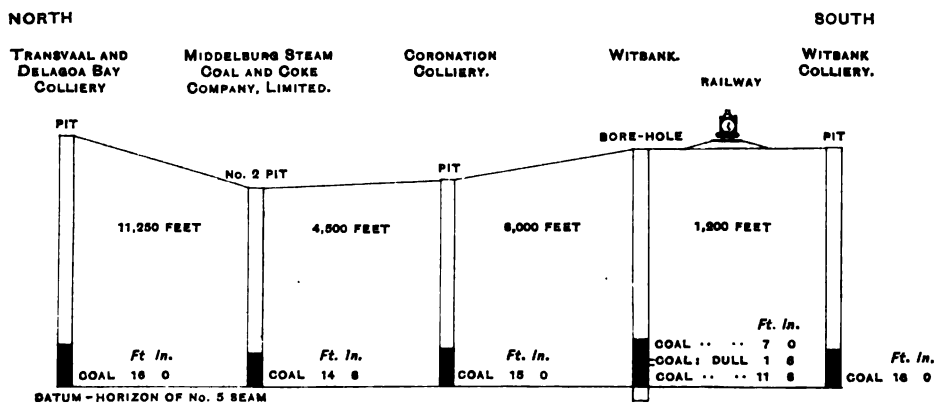
To illustrate Mr. J. J. Whitehead's "Notes on Coal in the Transvaal."

FIG. 2.—PLAN OF WITBANK DISTRICT.



Scale, 1 Mile to 1 Inch.

FIG. 3.—SECTIONS IN WITBANK DISTRICT.



Vertical Scale, 80 Feet to 1 Inch.

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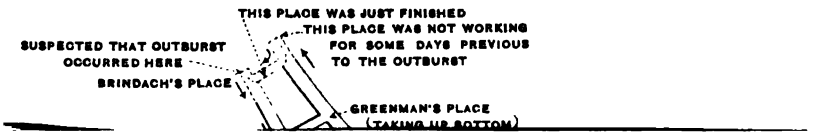
FIG. 1.—PLAN OF NO. 1 MINE.

MORRISSEY.



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To illustrate Mr. A. Ross' Paper on "The Circulation of Water in Steam-boilers."

FIG. 1.

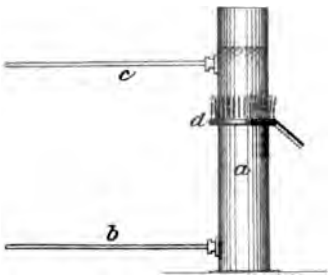


FIG. 2.

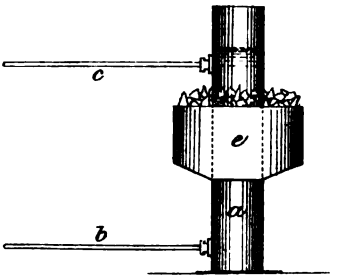


FIG. 4.

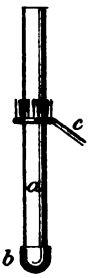


FIG. 5.—SIDE ELEVATION OF A LANCASHIRE BOILER.

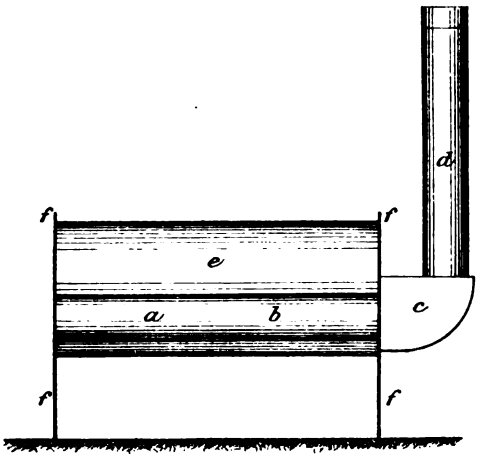


FIG. 6.—END ELEVATION.

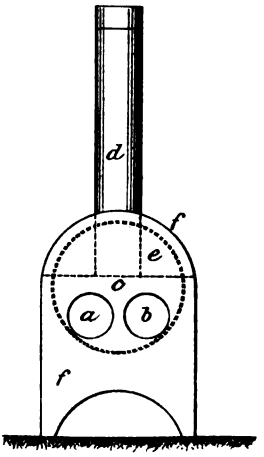


FIG. 3.

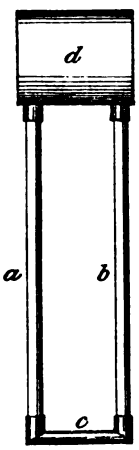
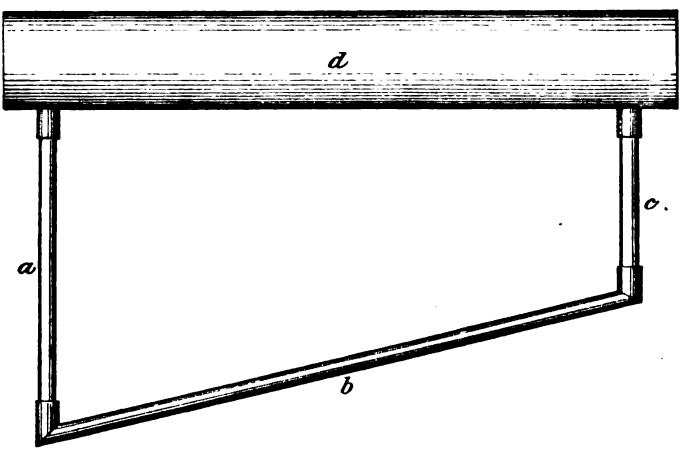


FIG. 7.—WATER-TUBE BOILER.



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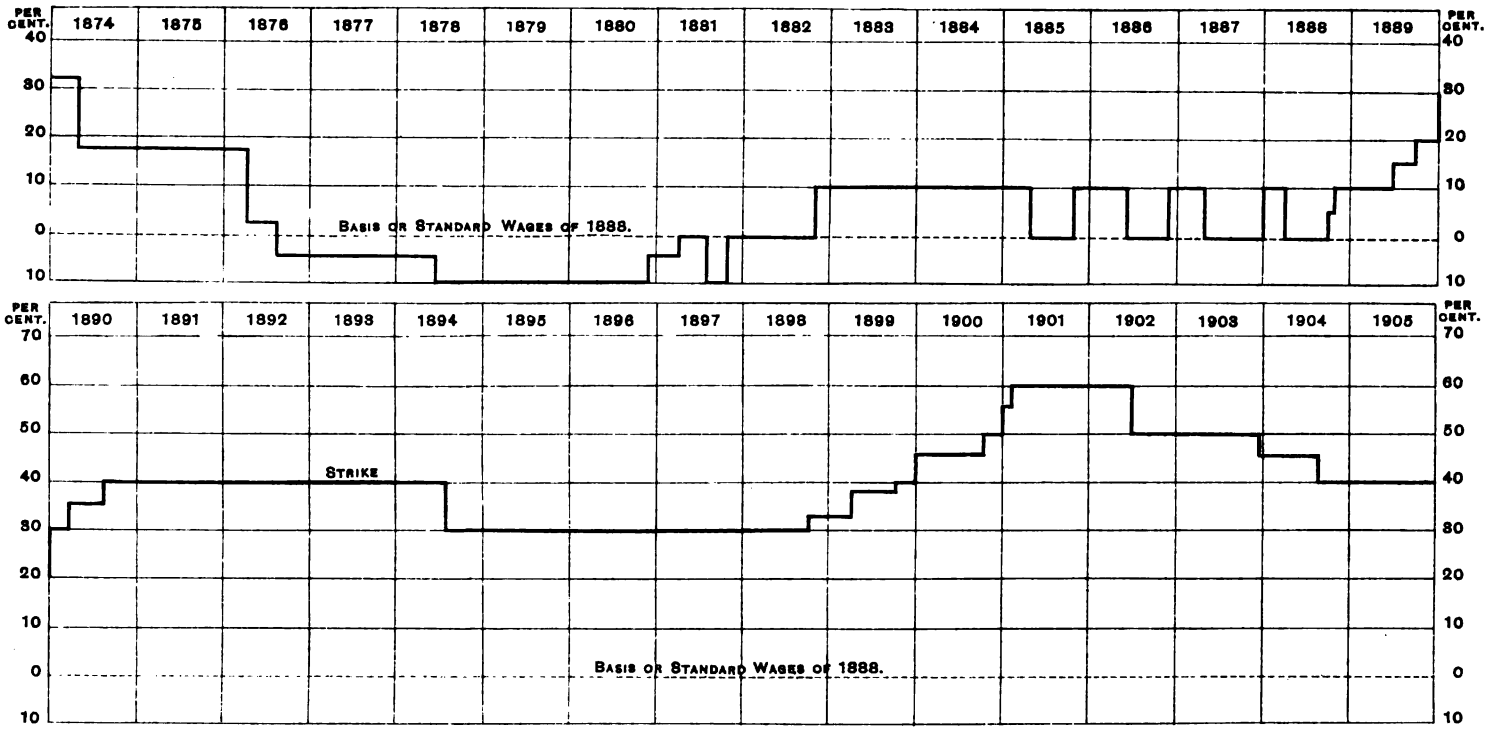
Transactions, 1905-1906.

To illustrate Mr. H. Bramall's "Presidential Address."

Vol. XXX., Plate IX.

DIAGRAM SHOWING THE VARIATIONS IN COLLIERS' WAGES IN RELATION TO THE BASIS OR STANDARD WAGES OF 1888.



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Vol. XXIX., Plate V.

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Transactions 1905 1906

To illustrate Mr. B. H. Thwaite's Paper on "Can Explosions in Coal-mines, with their associated Toxic Fatalities, be prevented."

FIG. 1.—ELEVATION OF THE APPARATUS.

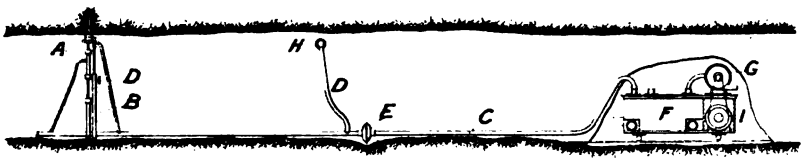


FIG. 2.—ELEVATION OF DUST-COLLECTOR, F.

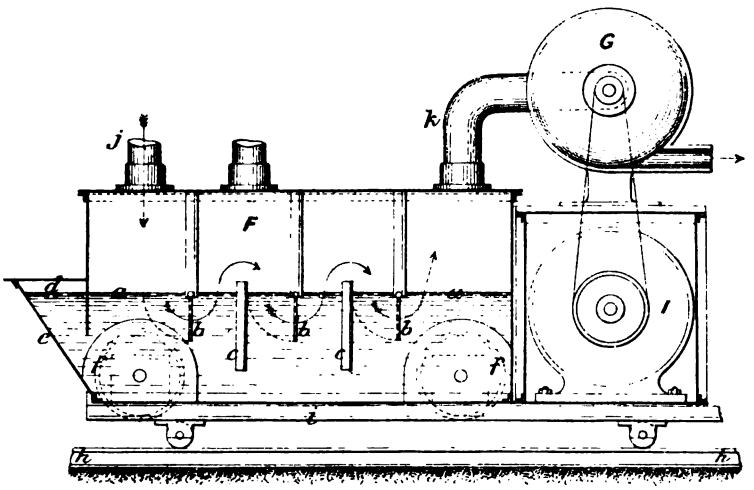


FIG. 3.—SECTION OF SUCKER-HOOD OR TERMINAL, A.

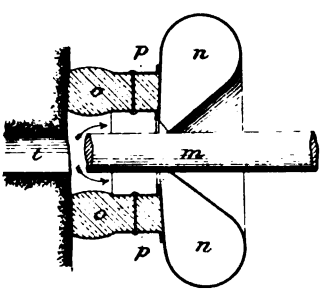
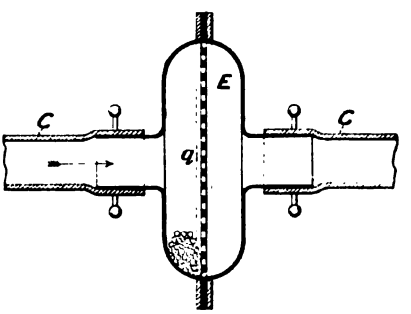


FIG. 4.—SECTION OF COUPLING, E, OF AIR-MAIN, C.



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Transactions. 1906 1906

To illustrate Mr. James Ashworth's Paper on

FIG. 1.—BONNETED CLANNY SAFETY-LAMP.
SHAKERLEY COLLIERY.

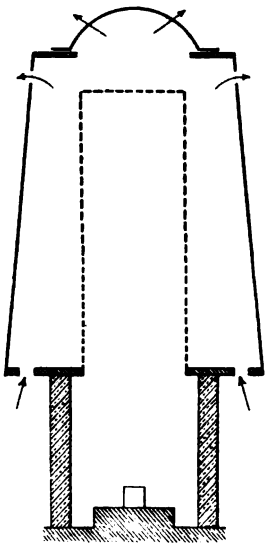

FIG. 2.—SAFE.

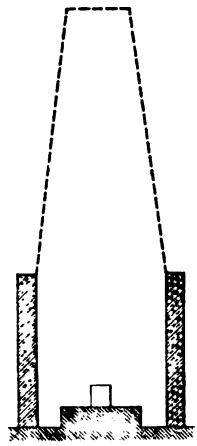

FIG. 3.

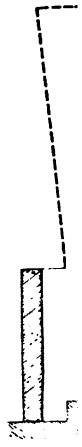

FIG. 6.—
CYLINDRICAL FORM OF GAUZE.

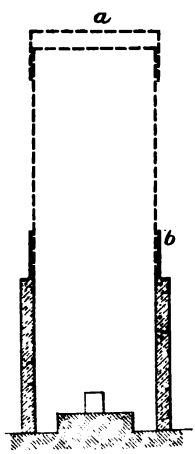

FIG. 7.—UNSAFE.

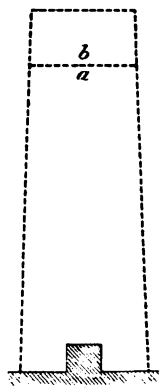

FIG. 8.—UNSAFE.

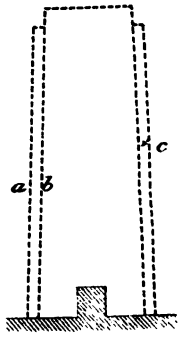

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Plate 7

Fig. 3.—Unsafe.

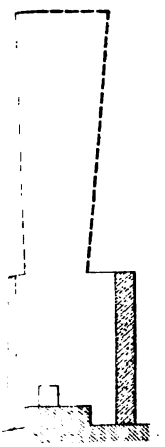


Fig. 4.—Unsafe.

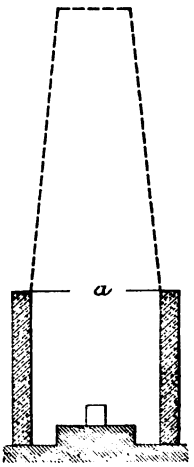


Fig. 5.—Conical Form of Gauze.

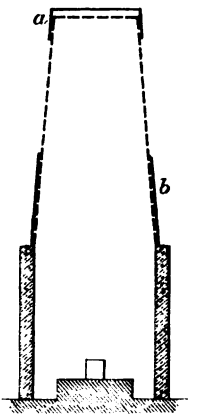


Fig. 9.—Unsafe.

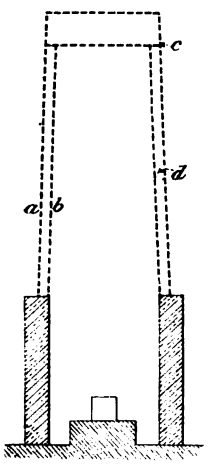


Fig. 10.—Evan-Thomas No. 7 Safety-Lamp

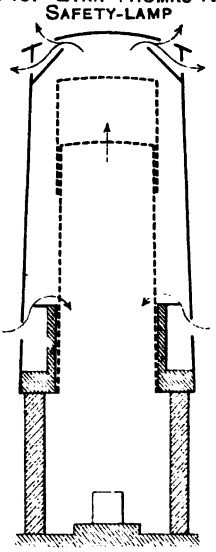
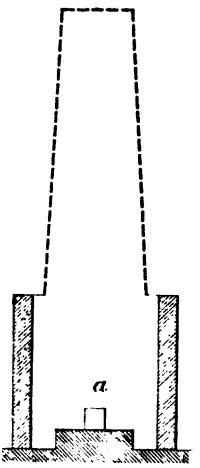


Fig. 11.



REFERENCES.

GLASS ..... SHEET METAL ——
WIRE-GAUZE ----- METAL
DIRECTION OF AIR-CURRENTS ..... ——→

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Plate 8

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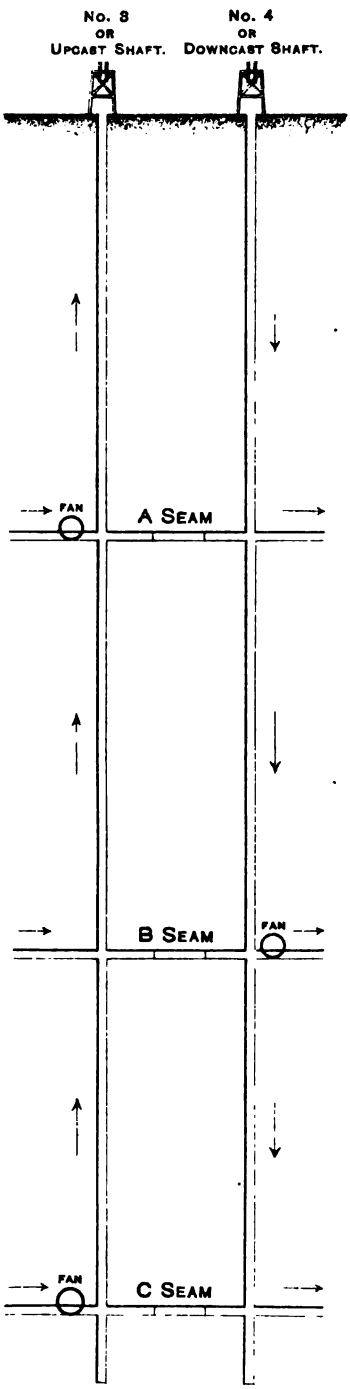
Transactions 1905-1906.

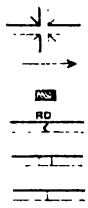
VOL. XXXI., PLATE V.

To illustrate Mr. A. J. Tonge's Paper on "Underground Fans as Main Ventilators."

FIG. 1.—SECTION.



REFERENCES.



AIR-CROSSINGS.
DIRECTION OF AIR-CURRENTS.
FANS.
RELIEF-DOORS.
SEPARATION-DOORS.
STOPPINGS.

FIG. 2.—PLAN.

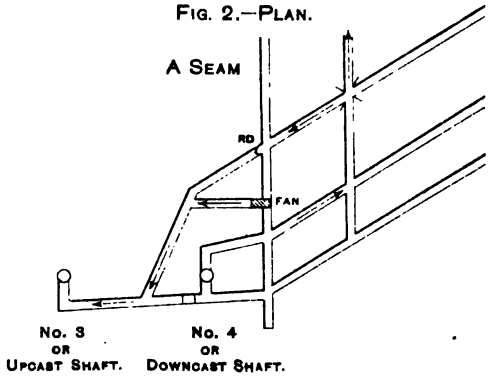


FIG. 3.—PLAN.

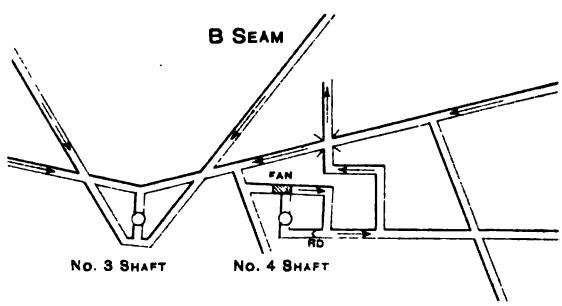


FIG. 4.—PLAN.

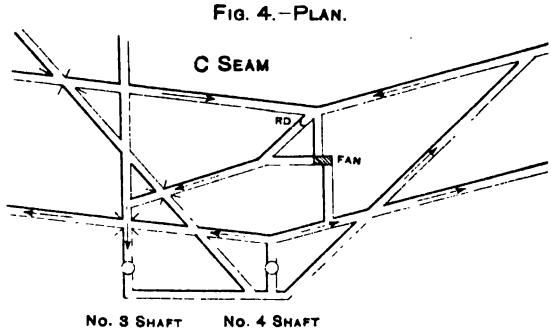


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Plate 7

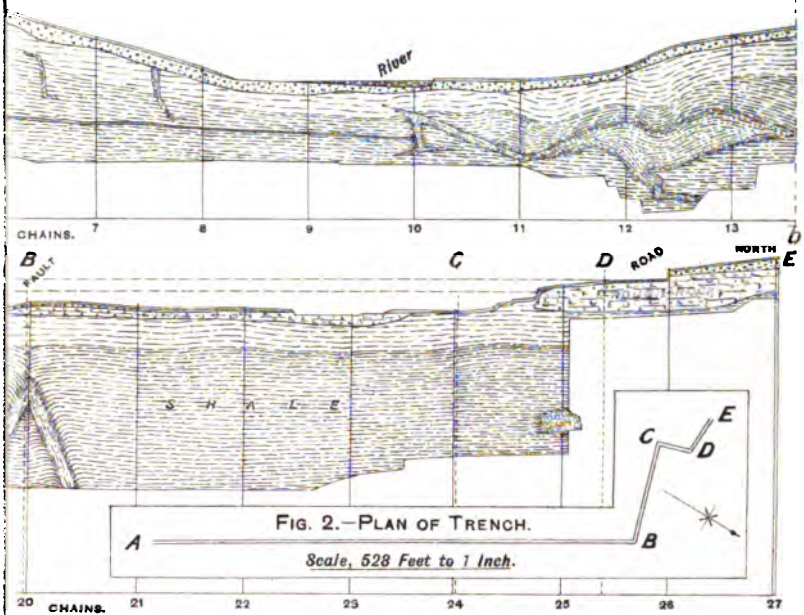
crete-trenches in the Little Don Valley." *Vol. XXXI., Plate XIV.*

SETT RESERVOIR.

OGICAL SECTION OF TRENCH.

a

EMBANKMENT, 817 FEET
ATER-LEVEL, 810 FEET



b

FIG. 2.—PLAN OF TRENCH.

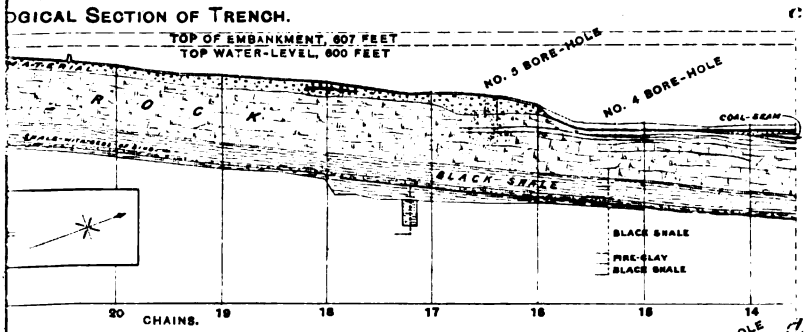
Scale, 528 Feet to 1 Inch.

e, 120 Feet to 1 Inch.

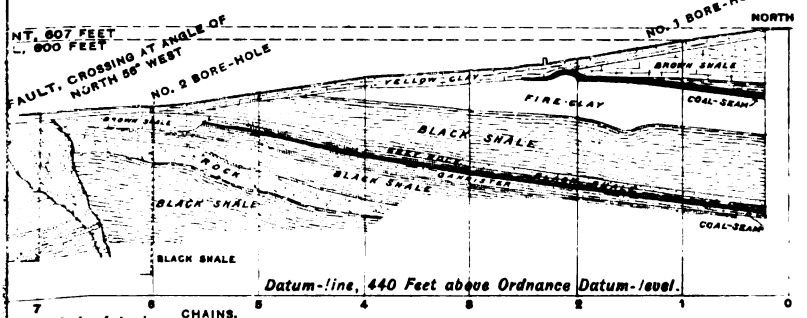
BANK RESERVOIR.

OGICAL SECTION OF TRENCH.

c



d



) Feet to 1 Inch

Vol. XXIX., Plate IX.

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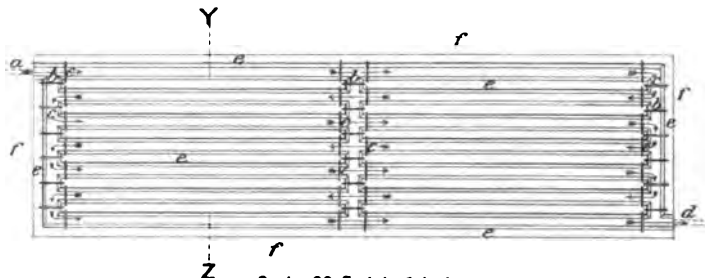
To illustrate Mr. W. Walls' Paper on "Alternative Schemes of Pumping and Supplying Water by Gravitation" etc.,

FIG. 1.—PLAN OF PRECIPITATION-POND



Scale, 32 Feet to 1 Inch.

REFERENCES.

- *a* WATER-INLET.
- *b* WOODEN SLUICES.
- *c* SLOTS FOR SLUICES.
- *d* WATER-OUTLET.
- *e* CEMENT-CONCRETE.
- *f* SOILING.
- ⟶ DIRECTION OF WATER-FLOW.

FIG. 2.—CROSS-SECTION OF PRECIPITATION-POND ON LINE YZ OF FIG. 1.

Scale, 32 Feet to 1 Inch.

REFERENCES.

A	EMBANKMENT OF EARTH.	*F*	PITCHING.
B	CONCRETE.	*G*	SOILING.
C	CLAY-PUDDLE.	*H*	CONCRETE-LINING.
D	GRAVEL.	*I*	CEMENT-RENDERING.
E	PITCHING.	*J*	BRICK-FACING.

FIG. 3.—CROSS-SECTION OF EMBANKMENT, LINED WITH CLAY-PUDDLE.

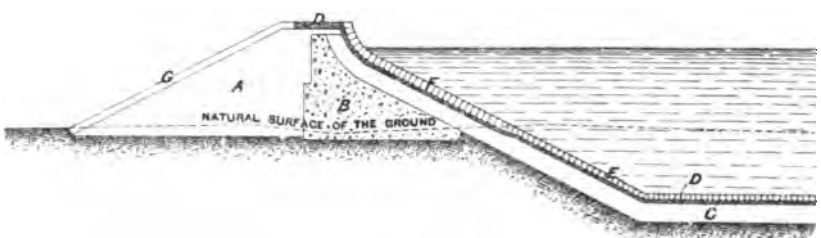
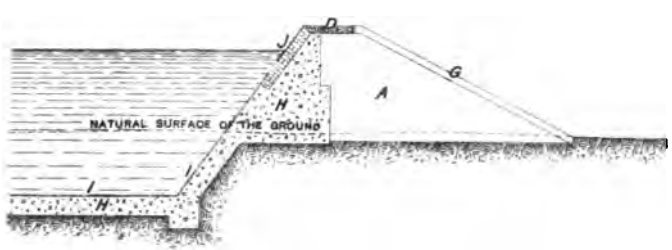


FIG. 4.—CROSS-SECTION OF EMBANKMENT, LINED WITH CEMENT-CONCRETE.



Scale, 16 Feet to 1 Inch.

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